PILOT SKILL DEVELOPMENT WITH IMPLICIT AND EXPLICIT LEARNING: CONSIDERATIONS FOR TASK COMPLEXITY

By

RYAN D. SULLIVAN

A THESIS PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE IN EXERCISE AND SPORT SCIENCES

UNIVERSITY OF FLORIDA

2000

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	12.Feb.01	THESIS

4. TITLE AND SUBTITLE
PILOT SKILL DEVELOPMENT WITH IMPLICIT LEARNING:CONSIDERATIONS FOR TASK COMPLEXITY

5. FUNDING NUMBERS

6. AUTHOR(S)
2D LT SULLIVAN RYAN D

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
UNIVERSITY OF FLORIDA

8. PERFORMING ORGANIZATION REPORT NUMBER
CI01-52

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
THE DEPARTMENT OF THE AIR FORCE
AFIT/CIA, BLDG 125
2950 P STREET
WPAFB OH 45433

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION AVAILABILITY STATEMENT
Unlimited distribution
In Accordance With AFI 35-205/AFIT Sup 1

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

14. SUBJECT TERMS

15. NUMBER OF PAGES
103

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT

ACKNOWLEDGEMENTS

I wish to express my gratitude to many people for their contributions in the preparation of this thesis. Extreme thanks are expressed to Dr. Christopher Janelle for his candid feedback, relentless attention to detail, and consistent support (without which, completing in one year would have been impossible). I would also like to thank the other members of my committee, Dr. Jim Cauraugh and Dr. Milledge Murphey for lending their support and knowledge to my research. I'm also appreciative of the efforts provided by Curtis Weldon for his support in the technical aspects of maintaining testing equipment for this study. Finally, I would like to thank the other individuals too numerous to mention, who provided support and knowledge in facilitation of this thesis.

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By

Ryan D. Sullivan

August 2000

Chairman: Dr. Christopher M. Janelle
Major Department: Exercise and Sport Sciences

The focus of the present study was to evaluate aspects of the learning process that aid expertise development for aircraft pilots. Research in learning strategies has recently focused on implicit and explicit learning to determine if it is more important to focus on conscious facts or unconscious procedural performance during the learning process. Of particular concern for the current investigation was to determine if explicit knowledge is necessary for automatic performance of complex cognitive motor skills such as flying.

Several recent studies have proposed that explicit knowledge may be detrimental for performance under the cognitive loads of stress. This study therefore examined groups of novice pilots who learned how to fly a flight simulator either implicitly or explicitly to see what effect the learning process had on performance during stress and a subsequent retention test. Participant scanning patterns were also analyzed using an infrared eye tracker to determine which group would exhibit superior attentional control.

Analysis revealed that the implicit group was able to match the performance of the explicit groups during acquisition trials but performed worse during the stress and retention periods. The explicit groups also fixated for longer on instruments that would delineate more expert scanning patterns. The results demonstrated that explicit knowledge for more complex tasks is not detrimental, and can lead to increased long-term performance.

CHAPTER 1
INTRODUCTION

A major objective of motor learning research has been to distinguish the characteristics of novice and expert performance, as well as to determine how the transition between these states occurs. As one progresses through the learning process, a high level of performance emerges that is both consistent and efficient in its use of physical and attentional resources. Achieving relative expertise over time is facilitated by the development of knowledge and skill through extended practice. Of particular interest for this study were the aspects of the learning process that aid expertise development for aircraft pilots.

Skill development for pilots involves the ability to overcome the cognitive demands placed on them during flight. A generally accepted notion is that the early stages of learning are very cognitively demanding (Schneider, 1985; Shiffrin & Schneider, 1977). Correspondingly, several researchers investigating the flight performance of novice and expert pilots concluded that increased cognitive demands during complex flight tasks resulted in decreased performance by novices (Bellenkes, Wickens, & Kramer, 1997; Gopher, Weil, & Bareket, 1994).

A contemporary area of research in the cognitive literature has been the investigation of how skilled performance, such as coping with increased cognitive loads, is achieved by experts, and which methods of acquisition affect the learning process. One technique that is commonly used to increase cognitive loads is the augmentation of stress levels. The current investigation therefore examined the transition of novice pilot performance over time, using different learning models, in an effort to discover which method of learning allowed the maintenance of superior performance when confronted with the increased cognitive demands invoked by stress.

Visual Search

Performance in flying is based on the pilot's ability to control the aircraft. One of the most important characteristics displayed by expert pilots that contributes to superior performance is attentional control (Gopher, 1993). Attentional control is the ability to adaptively change attentional strategies during complex tasks (Gopher et al., 1994). To assess the attentional resources of pilots, their attentional focus must be determined. Because flying is a visually dominant task, observing and interpreting visual scanning behavior during flight can adequately describe a pilot's variability in attentional control.

Several researchers have examined the differences between expert and novice pilot scanning patterns, providing a comprehensive overall picture of what expert pilots do while flying. Specifically, findings have indicted that experts have shorter dwells on instruments (Bellenkes et al., 1997; Fitts, Jones, & Milton, 1950; Tole, Stephens, Harris, & Ephrath, 1982), more visits to each instrument (Bellenkes et al., 1997; Tole et al., 1982), the rapid ability to detect deviations from normal parameters in instruments (DeMaio, Parkinson, & Crosby, 1978; DeMaio, Parkinson, Leshowitz et al., 1976), a scanning pattern that is flexible and changes according to the state of the aircraft at different times (Spady & Harris, 1983), and a better capability to maintain a critical variable, such as altitude, at a constant level (Bellenkes et al., 1997).

Questions that remain to be answered include, "What allows experienced pilots to achieve this expert status?" and "How is the transition made between relative novice and expert status?" Therefore, the purpose of this study was to evaluate the development of relative levels of proficiency through a comparison of scanning patterns and flight performance on aircraft flight simulation tasks under varied learning conditions.

Limitations of Visual Search Research

A variety of problems have rendered previous research on pilot visual scanning less than adequate. For example, much of the research in this area has focused on finding an optimal scanning pattern that can be taught to less experienced pilots. One of the problems with this approach is that scanning patterns continuously change between different pilots, maneuvers, and instruments (Fitts et al., 1950). Therefore, analysis made on a specific instrument panel layout must be repeated separately for each specific configuration of instruments of interest (Papin, Naureils, & Santucci, 1980). The most useful information that has emerged from these studies has been the general trends seen between expert and novice pilots as detailed above. The instrumentation used in the present experiment simulation was of a standard Cessna aircraft. While information acquired from this experiment is not completely transferable to other aircraft, the wide use of Cessna planes for standard private piloting and as an introductory plane for military pilots warrants the Cessna simulation pragmatically appropriate. Furthermore, the theoretical implications of this investigation are potentially applicable in a variety of contexts.

Another problem with past studies has been the use of a standard flight track to constitute indication of proper aircraft control. However, it is well known that a slight deviation from a normal flight track might not necessarily be bad. As Bellenkes et al. (1997) noted, variability exists between pilots in terms of when a procedure under examination is initiated, thus making it difficult to determine precise calculation of maneuver performance. As a result, there has been some difficulty in developing objective performance measurements for previous experiments. This problem was avoided in the present investigation by utilizing a task of straight and level flight, which provided an obvious standard for successful performance. As previously noted, experts are able to maintain variables better than novices, so this task naturally lends itself to expert and novice comparison.

Skill Development and Automaticity

The transition to an expert pilot, like any other learning process, involves several stages that vary in terms of acquired knowledge, attentional resources required, and variability in performance (Fitts, 1964). Eventually, experts achieve a state of relative "automaticity". Automaticity is characterized by performance that is fast (Logan, 1988b; Neely, 1977; Posner & Schneider, 1975), effortless (Hasher & Zacks, 1979; Logan, 1978, 1979; Schneider & Shiffrin, 1977), autonomous (Logan, 1988b; Kahneman & Treisman, 1984; Posner & Schneider, 1975; Shiffrin & Schneider, 1977), consistent (Logan, 1988b), unavailable to conscious thought (Marcel, 1983), and learned as a consequence of experience (Logan, 1988b). Expert pilots, as noted by the studies presented above, exhibit these characteristics. If a learning technique could be developed to provide a more efficient transition to an automatic state, then a skill could be obtained faster and exhibit far less variability under demanding conditions earlier in the learning sequence.

Implicit/Explicit Learning

The motive for investigating learning processes in the context of flight control is rooted in recent lines of research devoted to understanding the effect of stress on performance, and how performance variability is mediated by how skills are learned (notably, Bright & Freedman, 1998; Hardy, Mullen, & Jones, 1996; Masters, 1992). Of interest has been the acquisition of motor skills with special consideration for their robustness during stressful conditions. The implications of this research are important for flying because it can be considered a stressful task even during normal operation. Studies of these learning conditions have been directed towards determining better ways to prevent performance decrements under stress. With a focus on the transition from novice to expert pilots, the present investigation provided the opportunity to apply this same line of inquiry to the development of flying skill.

Two types of knowledge have been examined as playing a role in the transition to an autonomous performance state: explicit and implicit. Explicit knowledge involves the application of facts and rules during task performance (Masters, 1992). Implicit knowledge involves an increase in performance, or the acquisition of complex information, in such a way that there is no awareness that learning has occurred (Seger, 1994). The general question underlying the distinction is whether it is more important to focus on conscious facts or unconscious procedural performance during the learning process.

Before distinguishing the effectiveness of different types of learning, it must be possible to isolate the relative contributions of explicit or implicit processes in experimental paradigms. To address this need, Baddeley (1992) developed a system that allowed researchers to focus on each of these separate learning processes. According to Baddeley, explicit learning depends upon working memory to place facts and rules into conscious memory. Therefore, a way to prevent explicit learning would be to occupy working memory with the processing of task irrelevant information, thus rendering a person incapable of concurrently processing relevant explicit knowledge. Baddeley reasoned that a task of random letter generation during task performance would be an ideal way of obstructing access to task relevant processing. The random letter generation would occupy the working memory and not allow a person to use any explicit information for learning the task of interest. As a result, any task performance that was accompanied by concurrent random letter generation, called the Articulatory Suppression Task (AST), would mainly generate implicit knowledge.

The basis for the current study lies in the recent examination of the effect of stress on performance of golf putting, which utilized the AST task to differentiate the impact of implicit and explicit processes. Masters (1992) conducted a study with 40 participants, who were randomly assigned to five main groups. The explicit group received explicit instructions on how to properly perform a golf putt. There were two implicit groups, the implicit and implicit control, which were both given no instruction and were required to perform the AST dual task during skill acquisition. The implicit control group was not stressed during the final phase of the experiment. Finally, there were two control groups who received no explicit information and did not have to perform the AST. One control group was stressed in the final phase, while the other was not. Masters (1992) concluded that stress negatively affected performance among individuals who learned explicitly, based on their tendency for decreased putting performance during stressful conditions.

Increased stress levels however, did not adversely affect the implicit groups. The results seemed to demonstrate that implicit based performance was resistant to stress, while explicit was not.

Masters (1992) reasoned that explicit based performances were conscious processes, thus, thinking of the proper way to perform a putt under stress actually inhibited performance. Implicit knowledge however, is by definition, beyond description for the individual and therefore was not accessible, leading to minimal interference. This notion is consistent with the findings that when stress is initiated, internal thinking about the process of a movement is what leads to decreased performance (Baumeister, 1984; Kimble & Perlmuter, 1970; Wegner & Giuliano, 1980).

Hardy et al. (1996) conducted an examination using slightly different conditions than Masters (1992) and found the same results, in that both implicit groups performed better under stress. Bright and Freedman (1998) also performed a similar golf putting experiment, but they instead found that the implicit group decreased in performance while under stress. However, it can be argued that participants in the Bright & Freedman study had not achieved the same level of expertise as those in Masters (1992) or Hardy et al. (1996). As a result of these findings, there seems to be equivocal evidence with respect to the impact stress has on implicit and explicit based performance of motor skills. The present study expanded on this line of analysis of skill development by applying it to pilot expertise.

Limitations of Implicit/Explicit Research

Seger (1994) included as a criteria for implicit learning that information being learned must be complex, since simple patterns lend themselves to explicit learning.

Berry and Broadbent (1988) also found that when the relationship between input variables and the output is simpler and more obvious, tasks are performed in a more conscious, explicit manner. Perhaps the simplicity of a putting task prompted this decrease in performance because it is geared for an explicit state. In this investigation, implicit and explicit learning for both a complex and simple flight performance task were used to determine whether these differing models of skill acquisition influence the general learning process and performance under stress.

The inclusion of eye scanning with the present investigation also allowed the association of additional variables to provide for the distinction between learning groups. Comparing each participant's gaze pattern to the typical characteristics of an expert pilot described earlier presented an additional performance variable for each of the testing groups. The comparison of gaze patterns to expertise level and performance by each learning condition is very important in determining the benefits associated with implicit and explicit processes for complex, cognitive tasks.

Statement of Purpose

Of concern for the following study was examining the similarities and differences that existed between implicit and explicit learning with respect to flight performance and visual scanning characteristics. Visual search patterns were tracked throughout testing to determine the change in gaze behavior over time. The learning process was examined for novice pilots during the acquisition of both a simple and complex skill on a flight simulator. Using the AST task, differences in explicit and implicit performance were evaluated to determine their relation to complex, cognitive skill development.

Research Hypotheses

1. Group performance changes. It was expected that a normal learning curve would emerge for all groups, as demonstrated by the research on golf putting skills (Bright & Freedman, 1998; Hardy et al., 1996; Masters, 1992). Although groups were expected to improve over time, the characteristics of their improvement were expected to be different. Specifically, the performance for the implicit group was anticipated to be lower than the other groups due to the concurrent performance of the AST. Implicit performance was hypothesized to be lower during both the stress and retention phases as well, because of their inability to extract proper information from the instrument panel. All groups that performed the AST were expected to have a slightly decreased performance (Bright & Freedman, 1998; Hardy et al., 1996; Masters, 1992).

The implicit group was expected to exhibit considerable error reduction later than the other groups because it would take them longer to figure out what the instruments were, how to read them, and how to control the plane. Performance for those in the added explicit control group was expected to be high initially and similar to the explicit group because of their inherent knowledge of flight instruments. This combination was not done together in the past, however, and it was hypothesized that it could be possible for the working memory to be necessary for the association of explicit knowledge to actual flying. Therefore, it was predicted that the performance of this group would not be as high during skill acquisition, because they would either not be able to consciously recall the rules, or there would be interference with their conscious recall of information and their performance of the dual task. They were expected to perform slightly worse than the explicit group, but still above the implicit groups in both acquisition and retention.

2. Variability in scanning pattern. It was expected that the explicit learning group would initially have shorter fixation durations, more fixations, and more variable scanning patterns as compared to the other groups (i.e., scan patterns would be similar to expert pilots). This was anticipated because of their acquisition of explicit knowledge concerning the information and interaction of each instrument. The implicit learning group was expected to have a more constant and repeated fixation sequence pattern, representing an unconscious effort to find a suitable way to control the airplane (Spady & Harris, 1983). It was hypothesized that they would likely attempt to control one variable at a time because of their unfamiliarity in using the pertinent instruments for simultaneous control of all flight axis (altitude, airspeed, heading), resulting in higher variability in performance.

3. Information extraction. It was previously noted that more experienced pilots have shorter dwells that allow quicker data extraction, due to familiarization with instrument location and the information that each provides (Bellenkes et al., 1997). Thus, experts are able to detect deviant readings of indicators faster because they can obtain more information on a single glance. These patterns of scanning were expected to result in the explicit groups having faster response times during the slide information extraction task. The implicit group, however, was expected to show the steepest decrease in time through practice. Additionally, experts are more accurate at reading flight instrument information as well (DeMaio et al., 1978). The explicit

groups were therefore expected to exhibit less error when providing the slide information.

4. Effect of stress manipulation. Berry and Broadbent (1988) found that when the relationship between input variables and output was simpler and more obvious, then participants performed tasks in a more conscious, explicit manner. Flying is a more complex system to control than golf putting, as previously examined. It was hypothesized that there would be no decrement to explicit based performance in the stress condition. Seger's (1994) review of implicit learning included as a criteria for implicit learning, that information being learned must be complex, since simple patterns lend themselves to explicit learning. Therefore, it was hypothesized that implicit control would become more important for the control of complex systems, despite the amount of explicit knowledge present. This would provide an indication that explicit knowledge for complex actions would lead to higher initial performance levels without having any concern for performance degradation under stress later. Since it is predicted that increased performance for complex tasks is achieved through explicit knowledge of how to do a task, this was believed to be the best way to approach the learning process for complex actions.

5. Amount of explicit knowledge. Explicit knowledge recorded at the end of test completion was expected to be highest for the explicit group, with the explicit control second, control group third, followed by the implicit groups. It was hypothesized that complex actions requiring the use of cognitive working memory necessitate a base explicit knowledge for that performance (Anderson, 1982). Therefore the implicit groups and the control group were predicted to be unable to provide any explicit

information about flight dynamics, other than the way to properly read an instrument. Only the explicit groups were expected to exhibit knowledge of interrelations of flight dynamics and instruments.

Significance

Understanding the effect of stress on performance is important for aircraft operation since flying is performed in an inherently unstable environment, and in many instances, lives depend on its proper execution. Examining the change in pilots' attentional flexibility and their performance under stress after having been exposed to different learning conditions provides further insight into what ultimately allows experts to achieve higher performance, and whether explicit knowledge during skill acquisition is indeed detrimental.

CHAPTER 2
LITERATURE REVIEW

Researchers who have investigated differences in expert-novice pilot performance have determined several characteristics that provide for increased expert control of the aircraft. Attentional control appears to be one of the main contributors to performance differences (Gopher, 1993). While much emphasis has been devoted to the distinction of novice and expert pilot performance, little has been placed on the examination of the transition between these states. The focus of this investigation was therefore to determine how these differences in attentional control develop. While examining this change, it was also important to evaluate the effect of different learning models on flight performance and attentional control. In doing so, insight would be gained into what type of knowledge is required to facilitate advancement from novice to expert performance, as well as to provide superior performance under stressful conditions.

With these goals in mind, related literature and critical issues for performance development will be reviewed. Areas of research to be explored include visual scanning, attentional control and flexibility, automaticity, implicit and explicit learning, and skill acquisition. First, an explanation of the development of visual search in aviation will be discussed. Second, a rationale for the study of pilot expertise development will be provided. Finally, current research in implicit and explicit learning will be described as the basis for the present study.

Pilot Expertise

Moran (1996) outlined several components of expertise including 1) having more declarative knowledge, 2) having knowledge that is more detailed and better organized, and 3) performing better, faster, and more accurately. Expert pilots develop many skills such as these that help them maintain aircraft control during the complex, dynamic situations that occur during flight. One of the most important aspects of control is attentional flexibility. Flexibility can be defined as the ability to adapt and utilize resources to achieve the task at hand. Gopher (1982) noted that flying involves the ability to focus attention to relevant aspects of control and the ability to divide resources properly. The amount of attentional resources that are available is one of the critical limitations of human performance (Wickens & Gopher, 1977). For example, compared to an expert pilot, the resources and capabilities of a novice pilot are quite limited. They must therefore make effective use of their resources in order to achieve a high level of performance.

Pilot Attentional Control

In order to assess the attentional resources of a pilot, researchers must be able to determine where the pilot's attention is focused. Since flying is mainly a visually orientated task, a certain amount of the attentional control exhibited by a pilot can be determined by evaluating his/her visual search behavior during flight. There has been some question as to whether eye movements necessarily correspond to direct attentional shifts. Several researchers (Hodgson & Muller, 1995; Schneider & Deubel, 1995) have examined saccadic eye movements and subsequent visual attention to establish the level of correspondence. It is impossible to assume that once a saccade has been made, the person is will continue to direct their attention to the point of new fixation. However, results have consistently suggested that each time a saccadic eye movement is initiated, attention is forced to follow in the same direction. Researchers who have previously examined pilot scanning behavior in relation to performance (Bellenkes et al., 1997; Fitts et al., 1950; Wetzel, Krueger-Anderson, Poprik, & Bascom, 1996) have assumed a relationship between eye movement and attention because of the difficulty to extract information from a flight instrument without actual fixating on the instrument itself. Furthermore, in light of the fact that all performers in this investigation were novice pilots, this assumption seems to be a justifiable one. Wetzel et al. (1996) additionally noted that the fine detail needed to accurately read an instrument is only achieved when an object is stabilized on the fovea to allow the maximum amount of information extraction to occur.

The knowledge that the visual search pattern reflects a pilot's attentional control is important because it allows one to make certain inferences from the observed data. Analysis can designate what instruments the pilot looks at, for how long, and in what order. Consequently, the reconstruction of actual scanning patterns over time is possible, allowing researchers to determine changes in the order of information extraction and processing. Relating these characteristics to flying performance has been the foundation of most expert/novice comparisons between pilots.

Research in Pilot Scanning

Research in the area of pilot scanning behavior began with a study by Fitts et al. (1950). The experimental setup included two mirrors, which were arranged in the middle of the instrument panel that reflected the pilot's gaze and a stopwatch onto a

35mm motion picture camera set up behind the participants. For each of the 40 pilots tested, reference photographs were taken of them looking at each instrument, which were then compared to the recorded pictures taken during flight. Two 30-second records of an instrument landing approach were taken for each pilot. Recordings of the experiment tapes were analyzed frame by frame and the pilot's point of gaze was determined along with the fixation numbers and time of fixation. While this early study was ecologically valid because it was recorded during an actual flight, the gaze was merely a best guess estimate of actual eye position. The main purpose of the study was to provide information for the development of easy-to-read instruments and better instrument groupings. Fitts, therefore, made observations as to the important linkages between instruments for the C-45 aircraft, in which testing was conducted. A limitation to the application of the information gained by this was noted by Fitts in his conclusion when he stated that, "eye movements vary from pilot to pilot, from maneuver to maneuver, and from instrument to instrument" (Fitts et al., 1950).

These techniques, although revolutionary, were obviously limited by the available equipment. For years, a pilot's direction of attentional allocation could not be carefully identified nor measured with enough reliability to make accurate predictions. Over time advancements in the area of visual gaze calculations led to the development of infrared eye trackers that are readily used in many areas of research today. The full explanation of these technological developments is beyond the scope of this paper (For a review see Ditchburn, 1973). During transition to modern day equipment, many intermediate methods were cumbersome and difficult to analyze, which directly led to a shift away from eye tracking to a greater focus on the attention and information extraction realm of pilot expertise.

One such experiment by DeMaio et al. (1978) is a prime example. They tested the error detection performance differences between student and instructor pilots (IP's) on the T-37. The error of interest was a deviation of one of five instruments from established acceptable parameters for a predetermined course. The visual display consisted of a slide shown from a rear projection screen. There were two levers for signaling correct and incorrect responses. From the response time patterns, it was determined that the students looked at the instruments sequentially, while the IP's did not display such sequential pattern and were thus able to detect the erroneous readings faster and more accurately. The results seemed to suggest that experienced pilots readily use their peripheral vision more for the scanning of instrument panel displays. As students had more time to experience the multiple channel input, their reaction time to error detection gradually decreased as they became more familiar with the system.

The development of modern eye-tracking equipment once again thrust the research toward the detection of scanning pattern differences. Despite Fitt's recognition that scanning patterns continuously change between different pilots, maneuvers, and instruments, research in this area has continued to be driven by a desire to identify optimal scanning patterns among pilots (e.g., Papin et al. 1980). An ongoing series of recent experiments by Wetzel et al. (1996) has continued to examine this area. Tests were conducted to determine whether analysis of scanning patterns could be used to identify superior scanning strategies between expert and novice pilots in order to increase effective training strategies for a particular aircraft. Thus far, the visual scanning patterns of pilots in three different aircraft simulators have been analyzed. The simulators tested include the T-37, the F-16, and the F-16 LANTIRN. The researchers noted that they were able to create a series of training tapes that demonstrated efficient scanning patterns for complex situations. The result of these experiments may in fact be useful, but the drawbacks are obvious, in that each study and analysis made must be created separately for each specific configuration of instruments, because scanning patterns for specific instrument panels are not transferable (Papin et al., 1980). The only truly useful cross-application information from these studies has been the general trends seen between expert and novice pilots.

Many more studies have focused on the more general differences between expert and novice performance. Bellenkes et al. (1997) studied 12 novice and 12 expert pilots who flew a 7-segment simulation pattern while cockpit instrument panel scanning was recorded. Segments contained varied heading, altitude, and airspeed. Different segments included different combinations of constant and varying degrees of each of these three parameters. They consisted of one variable changing, to all three being changed at the same time. The necessary changes for each segment were displayed in an instruction box displayed on the instrument panel. Each pilot performed four consecutive 13-minute missions. Bellenkes et al. (1997) concluded that experts were able to extract the information more efficiently; they were able to adapt their scanning pattern through different maneuvers; and they were superior in their ability to maintain proper aircraft control. Performance for this experiment was calculated by a deviation from an established flight path. The problem with these studies with a standard track is that a slight deviation from normal might not be bad. As the researchers noted, there was a variation between pilots in terms of when a procedure was initiated, thus making it difficult to determine precise calculation of maneuver performance. As a result there has been some difficulty in developing objective performance measurements.

Despite the limitations of previous research, the preceding studies have revealed many important characteristics exhibited by experts during flight. It has been demonstrated that in general, experts: have shorter dwells on instruments (Bellenkes et al., 1997; Fitts et al., 1950; Tole et al., 1982), exhibit more visits to each instrument (Bellenkes et al., 1997; Tole et al., 1982), have the rapid ability to detect deviations from normal parameters in instruments (DeMaio et al., 1978; DeMaio et al., 1976), display a scanning pattern that is flexible and changes according to the state of the aircraft at different times (Spady & Harris, 1983), and are better at maintaining a variable that is to be held constant (Bellenkes et al., 1997).

While it is important to realize differences between the groups, a more valuable question, in terms of application of this knowledge, is to assess how the transition from expert to novice occurs. What allows experienced pilots to achieve expert status? No study has yet addressed the transition between these two states in order to answer this question. Noting the established differences between expert and novice pilots mentioned above, the focus of this study was to examine the learning process in an attempt to explain how these differences are established.

Skill Development Process

In order to understand what affects the learning process, the general stages of learning must first be explained. Fitts (1964), the pioneer of visual search in aircraft, established one of the most widely accepted descriptions of skill acquisition. In his analysis, he described the process as consisting of three major stages: cognitive, associative, and autonomous. Each phase exhibits specific amounts of increased knowledge, attentional resources required, and variability in performance. The initial, cognitive phase is when an individual focuses mainly on thoughts of how to perform the activity. As a result of having no prior experience for some movements, conscious effort is a necessary requirement for proper execution. During this stage a person searches for an action that will lead to successful performance. Because proper technique has not been established, performance is usually inconsistent and variable. Large gains in performance are generally seen during this stage, as individuals begin to understand the variables involved with task performance. The cognitive phase was a main focal point for the current investigation. Of interest was the examination of performance changes to determine if explicit knowledge is necessary for rapid improvement for complex cognitive skills.

Next, the associative phase is characterized by the refinement of a chosen technique. Movements become more consistent as the person produces smaller adjustments to these actions. Finally, as the person progresses to the final autonomous stage of learning, few changes are made to the motor program. Performance continues to increase with additional practice, although at a reduced level. In the transition to this stage, the cognitive processes necessary to maintain proper control are gradually reduced. This allows attentional resources to be released for other purposes.

Several characteristics of expert pilots have been examined in previous research based on these observations. Bellenkes et al. (1997) established three main criteria that they believed provided superior aircraft control for expert pilots. These included automaticity (the ability to extract information from the cockpit efficiently), a clear mental model (the innate understanding of the relationship between instruments and methods of aircraft control), and attentional flexibility. The present investigation addressed each of these components while directly addressing the stages of learning through development of these skills.

Automaticity

The ultimate goal of learning a new skill (e.g., flying) is to achieve an automatic performance state through practice. When this condition, called automaticity, is reached, several characteristics are generally noticed. Automaticity is fast (Logan, 1988b; Neely, 1977; Posner & Schneider, 1975), effortless (Hasher & Zacks, 1979; Logan, 1978, 1979; Schneider & Shiffrin, 1977), autonomous (Logan, 1988b; Kahneman & Treisman, 1984; Posner & Schneider, 1975; Shiffrin & Schneider, 1977), consistent (Logan, 1988b), unavailable to conscious thought (Marcel, 1983), and learned as a consequence of experience (Logan, 1988b).

Certainly expert pilots, as noted in the aforementioned studies, exhibit these characteristics. Descriptions of these properties are useful in analyzing what automatic performance is, however, it remains unclear how this state is achieved. In order to make the comparison of automatic processes to learning and skill development, the different views of automaticity development will be examined. This will become important when one attempts to explain the differences seen in previous research between expert and novice pilots. Two primary views of automaticity have emerged. One is defined as the ability to overcome resource limitations, while the other defines automaticity as a memory phenomenon that allows a large amount of data to run through an efficient process (Logan, 1988a). The two approaches will be described next.

Modal View of Automaticity.

The first explanation of automaticity is the modal view. It is called the modal view because of the "mode" or process that a person goes through in developing automaticity. The modal view is defined by the gradual reduction in attentional control needed to perform an action. Since automaticity is defined as performance without conscious thought or attention, many believe that this process is what explains the development of automaticity (Hasher & Zacks, 1979; Logan, 1978, 1979; Posner & Schneider, 1975; Shiffrin & Schneider, 1977). The modal view suggests that as a task is practiced, less attentional resources are needed (Navon & Gopher, 1979; Logan 1988b). In accordance with this view, attentional resources are the main factor that limits performance. With experience, actions that provide success or better performance are strengthened. When a skill is practiced, the attentional control needed to achieve the same level of performance is decreased. As noted by Bellenkes et al. (1997) earlier, the cognitive demands of the flight task resulted in decreased performance by novices in their experiment. Alternatively, experts tend to have more attentional resources, allowing a more flexible scanning pattern and faster reactions to flight variables (Spady & Harris, 1983).

Instance/Memory Theory of Automaticity

The memory view also attempts to explain how the transition from novice to expert occurs, but proposes that limitations in performance are not due to a lack of resources, but rather to a lack of knowledge. According to this theory, a novice can gain specific answers through practice that can be applied later in the same or similar situation. Proponents of the memory view argue, that people remember the experience of doing something, and thus remember these actions for future interaction with the environment. Eventually, when novices have learned enough responses, they will achieve the automaticity exhibited by expert performers. The increase in automatic behavior is due to the fact that it is easier for the individual to pull the correct response from prior experience (Logan, 1988b), suggesting that it would merely be the amount of time a pilot has flown which would create increased performance.

Whether one prescribes to the resource or memory theory, the end result of a highly practiced task is a certain level of automaticity. A general assumption is that the more one performs a task, the more skilled a person becomes. Because automaticity is the essence of the learned task, skill acquisition is dependent on the rate by which a skill becomes automatic (LaBerge & Samuels, 1974; Logan, 1988b). The goal of the learning process then, would be to create conditions that aid in the transition to an automatic performance state. Therefore, another goal of this study is to determine how automaticity is best achieved for flying by influencing the knowledge provided to participants before flying the simulator.

Implicit and Explicit Learning

Because automatic performance requires less control, a recent area of interest among cognitive psychologists has been the distinction between an unconscious, implicit way of learning and conscious or explicit learning. The goal of such research is to examine how implicit and explicit learning relate to each other, and how they can lead to superior, automatic performance. The premise behind examining these two areas is their apparent relation to the automaticity views focusing on resources and knowledge as described above. If it is possible to specify a learning technique that would provide a more efficient transition to an automatic state, then a skill can be obtained faster and exhibit far less variability under demanding conditions. To determine how implicit and explicit learning are related to automaticity each must be examined further.

Explicit Learning

Explicit learning develops a skill by focusing on the facts, or ideas fundamental to performance. Explicit knowledge involves the application of these facts and rules during task performance (Masters, 1992). Because a person is able to think about the rules during the learning process, explicit knowledge is a controlled, conscious process (Reber, 1993). Because explicit learning is based on conscious thought, many researchers suggest that working memory is where explicit knowledge is processed. This distinction will become important later when theory application is made for this experiment.

Implicit Learning

While explicit learning involves conscious thought patterns during learning, the converse is true of implicit learning. Implicit learning involves an increase in performance, or the acquisition of complex information in such a way that there is no awareness that learning has occurred (Seger, 1994). The result is knowledge of abstract representations that are not available to consciousness, or easily verbalizable (Lewicki, Hoffman, & Czyzewska, 1987; Reber, 1989, 1993; Seger, 1994). Implicit learning typically leads to actions that are rapid, smooth, and proficient (Reber, 1993).

The distinction between explicit and implicit learning seems simple enough; one is conscious, the other is not. Problems arise, however, upon examination of the nature of each type of learning. Since implicit learning, by definition, is unconscious, it has been difficult to determine whether it even exists, let alone how it changes over time. Researchers have pointed out that the differences between performances can be explained without creating this unconscious learning idea upon which implicit learning is based (Shanks & St. John, 1994). Much of the early research in this area, however, was developed to demonstrate the actual existence and acquisition of implicit learning.

Research On Implicit Learning

There have been two main areas of research dealing with implicit learning. Both have focused on the acquisition of task relevant knowledge without conscious awareness of its development. The initial investigation into the nature of implicit learning was Reber's analysis of artificial grammar learning (Reber, 1967). The study involved the memorizing of short lists of letter strings constructed from a synthetic grammar. A typical example would be VVTRX or another similar string of letter combinations. The letter strings were constructed from an established artificial grammar, and, as a result, followed a set of rules in their construction. The participants being tested, however, were unaware of these patterns during memorization. After memorizing the letter strings, they were informed of the existence of the grammar, and were subsequently told that all of the letter strings they had memorized conformed to it. They were then given a new list of letter strings, and were asked to delineate grammatical from ungrammatical strings. Despite knowing the letter strings and being told of the existence of a grammar, the participants were unable to verbalize the grammar. Even with this apparent lack of basis for discriminating grammatical from ungrammatical strings, participants were still able to perform the task at a level of proficiency that was beyond chance. Reber's (1967) was the first study to demonstrate implicit learning. Even though the participants could not verbalize the rules of the grammar, somehow through practice, they were able to apply it.

In another branch of research, Broadbent (1977) studied implicit learning involved with the control of complex systems. Participants directed a simulated transportation system in which they had to maintain the number of people using buses and the number of empty car parking spaces in a parking lot. These variables were controlled by changing the interval of bus stops and the price of parking. Similar to Reber's experiments, an underlying equation related these variables, but was unknown to the participants. Participants improved performance with practice as expected, but did not improve their ability to determine the relationship within the model they controlled. Individuals were able to control the systems better if they were not told the underlying rule. Thus, the traditional view on the transition from explicit to implicit learning and the processes utilized in teaching methodology were questioned. From both of these avenues, it can be reasoned that it is possible for someone to improve and explain their actions, but not have any justification for why they did so. Implicit learning is used to describe this pattern of performance increase without the ability to explain its occurrence.

Reber (1976) extended his analysis on artificial grammars by comparing a group that memorized letter strings without knowledge of their grammatical base, and those that learned the strings after being told that a pattern existed. Results illustrated that those looking for a hidden grammar performed worse in the grammatical classification test. Similarly, Berry and Broadbent (1984) also established that participants who were able to better control a complex, dynamical system knew less about the operation of the system. In their study, even when directed on how to reach the targeted value, and despite the participants' increased ability to answer questions on the system's operation, participant's performance still did not increase. Once again this analysis provided further support for the existence of implicit learning. There has been considerable debate concerning these findings, however.

Considerations for Automaticity

The application of implicit and explicit knowledge for the current study is to examine how each is related to automaticity. Converging lines of evidence indicate that practice of an activity results in the action being rapid, smooth, and proficient. There has been some confusion, however, in terms of what is exactly meant by implicit and explicit learning in relation to automaticity. Each can be viewed as a final state rather than a transitional learning process, resulting in a simplified description of implicit processing as fast and automatic, and explicit as slow and thought out.

Implicit is explained as the increase in performance without an increase in verbalizable knowledge. Because it is perceived as unconscious, an implicit process usually is felt to be automatic as well, as it is something that is done without thinking. This notion however does not take into account the learning process. Simply because an action holds automatic characteristics, does not mean that it is implicit. For example, it is possible for a rule and fact-based action to become automatic over time as well. A good example of the transfer to automaticity would be driving a car. What once was a carefully planned and cognitively controlled process, such as the rules of the road and how to control the car, becomes automatic after many years of driving experience. Anderson (1987) described this process as procedural memory, where explicit declarative knowledge is transformed into non-conscious procedures. Information that once was conscious, transforms into an automatic, efficient, and unconscious process with enough practice (Baars, 1988; Kihlstrom, 1987).

The interest and debate then is not necessarily in the explicit and implicit processes themselves, but rather how these knowledge types are used during the learning process to reach automaticity and the resultant affects they have on future performance patterns.

Importance of Implicit and Explicit Learning

The importance of implicit and explicit learning can also certainly be applied to the question of how skill is obtained for pilots through practice. Is it merely the more implicitly based automatic control created from practice over time that creates improved skill, or is it an increase in verbal knowledge of rules and interactions that allows this process to occur? Those questions relate back to the original discussion of the difference between modal and instance views of automaticity. It was noted earlier that the earlier stages of learning are cognitively demanding for novices. If learning is constrained by capacity, as the modal view states, then it would be better to let the participants learn more implicitly with less information so they could naturally develop increased performance as they perform the task and are able to cope with the resource demands of flying. However, if automaticity is based more on the memory view, the more information that could be provided to the novice, the better they should be able to adapt and perform while flying. The question as to the importance of knowledge base on performance of novice pilots was the primary focus of this investigation.

Chicken or the Egg?

Much of the debate regarding implicit and explicit learning has concerned what the requirements for each type of learning have been, and whether each relies on the other, or are obtained separately. Berry and Dienes (1991), in their comparison of implicit memory and implicit learning, stated that they were both independent of explicit learning. Reber (1993) and Seger (1994) also both point out that implicit knowledge can be gained without first having a foundation of explicit knowledge.

Others, however, believe that explicit knowledge is first required for implicit to appear. Fitts' (1964) explanation of skill development has its foundation in the cognitive stage where a learner receives information about a skill in the form of facts. The cognitive or explicit nature of this function is the basis for skillful performance. Anderson (1982) argued that in order to progress from knowledge to behavior, a person must go through an interpretive stage. In other words, one cannot make unconscious patterns of something one cannot even perform, and performance is usually gained by explicit knowledge of how to do a task. In line with this analysis, Underwood and Bright (1994) asked the question, "Is it necessary to be conscious of an event in order to perceive it, to remember it, or to incorporate it into our abstracted representations? (pp. 1)" They surmised that it is possible that implicit learning is simply the subconscious coordination of relationships between explicit rules; a simple analysis. Driving, once again, provides a good example. Some people know how to get places without being able to describe to someone else how to get there.

Still others believe that whether one learning mode depends on the other or not, it is obvious that they can be gained at the same time. Seger (1994) argues for the parallel development of implicit and explicit knowledge, since it would be impossible to achieve a task that was purely either implicit or explicitly based. As a result, the two forms of learning would not have to be mutually exclusive.

Implicit/Explicit and Stress

Current knowledge suggests that the ultimate goal of practice is an automatic state, and that there are several theories on how this state is achieved. Implicit and explicit knowledge are used to achieve expert status. The remaining question is whether a focus on one type of learning is superior, and what implications each type of learning has for performance under varying environmental conditions. In other words, how might performance in variable situations be influenced as a function of the learning process to which one has been exposed?

The motive for investigating learning processes in the context of flight control is rooted in a recent line of research devoted toward understanding the effect of stress on performance and how performance variability may be mediated by how skills are learned (notably, Bright & Freedman, 1998; Hardy et al., 1996; Masters, 1992). Of interest has been the acquisition of a motor skill with special consideration for its robustness during stressful conditions. As was discussed earlier, this is important for flying because it is inherently a stressful task. Research into these learning conditions can help determine better ways to prevent performance decrements under stress. The general question, once again, is whether it is more important to focus on conscious facts and knowledge or to rely upon unconscious procedural performance.

Basis for AST

Before discussing the relationship between stress and explicit and implicit learning, the means by which researchers ensure that a task is only learned through either explicit or implicit processes will be briefly described. The basis for distinction between tasks based on each type of learning relates to its access to working memory. Baddeley (1992) established a theory for the structure of working memory, which contained three mechanisms: a central executive system, an articulatory loop, and a visuospatial sketchpad. The central executive system involves focusing attention, interacting with memory, and coordinating the other two components. The articulatory loop holds limited verbal information, while the visuospatial sketchpad holds limited visual images and other spatial information. Based on his theory, Baddeley concluded that a task of a random letter generation by a participant during task performance would be an ideal way of obstructing the central executive system. As noted earlier, it is believed that explicit learning depends on the central executive of working memory to place the experiences into conscious memory. As a result, any task performance that involved this random letter generation, called the Articulatory Suppression Task (AST), would only generate implicit knowledge. Hayes and Broadbent (1988) supported this analysis by concluding that acquisition of explicit knowledge is impaired by a concurrent, memory-demanding task.

Research Using AST

Of concern in this review is the research that has examined the difference between implicit and explicit learning using this AST procedure in relation to performance under a competitive stress manipulation. Masters (1992) used the AST in his initial study of the effects of stress on the performance of a golf-putting task acquired under either implicit or explicit learning conditions. The stress manipulations in the form of evaluation apprehension and competition effect were implemented during the final test session. A declared "expert" golfer, who watched the participant's technique, conducted the evaluation. The incentive was in the form of increased payment if task performance was high.

Forty participants participated in 5 sessions of 2 sets of 50 putts. The 40 participants were broken into 5 main groups. The explicit group received explicit instructions on how to properly perform the putt. There were two implicit groups, the implicit and implicit control, which were both given no instruction and were required to perform the AST dual task during skill acquisition. The implicit control group was not stressed during the final phase. Finally there were two control groups that received no information and did not have to perform the AST. One control group was stressed in the final phase, while the other was not.

Masters concluded that the stressors in the final test session had a negative effect on performance for explicit learning because of the decreased performance exhibited by the explicit group in the final stress phase. The implicit group however, maintained high performance levels (Masters, 1992). More specifically, both the implicit group that was stressed in the final test phase and the implicit control, which did not receive the stress, showed improvement. The results seemed to indicate that implicit based performance was resistant to stress. As further evidence that explicit knowledge maybe hindered during stress, Masters cited the results for the control group. The control group was not given any explicit knowledge prior to task performance, but because they did not perform the AST during practice, they were also able to acquire self-generated explicit knowledge over time. Because participants had some explicit knowledge, this group also had a performance decrease during the stress condition. By requiring each participant to write down their knowledge after testing, he demonstrated that the explicit group indeed maintained the most knowledge, followed by the control group. The results demonstrated the possibility that acquiring motor skills based on the conscious thinking of how to properly perform a task could actually lead to decreased performance in a competition setting. This premise would have important implications for the learning process of pilots, because generally there is a large base of explicit knowledge that is stressed prior to gaining any experience.

Performance Differences

The difference established in Masters study was explained to be the result of the consciousness difference that exists between explicit and implicit knowledge. Implicit knowledge inherently is automatic, and as has been discussed, explicit knowledge can be used to achieve a similar level of automaticity. Explicit based automaticity however, is based on conscious processes, and therefore has the ability to slide back into this format. In other words, a process that developed into an automatic nature over time once again might become a more conscious, controlled, thought out process in an attempt to achieve better performance. In contrast, implicit knowledge is beyond description for an individual and therefore has nothing to slide back upon. According to current theory on the topic, when stress is initiated the internal thinking about the process for the explicit group is what leads to decreased performance (Baumeister, 1984; Kimble & Perlmuter, 1970; Wegner & Giuliano, 1980).

Continued Research

A weakness of Masters' study was that the implicit group was not required to complete the AST during the stress condition. The removal of the dual task could have been the cause of the performance increase for the implicit group. Any positive effect of removing the dual task could have overridden any negative effects that the addition of stress could have caused. As a result, Hardy et al. (1996) replicated Masters (1992) work, but added an implicit group, which performed the AST during the stress condition as well. With the additional manipulation, Hardy et al. found the same results as Masters (1992), in that both implicit groups performed better under stress, whether they were performing the AST or not. This once again presented further support for implicit learning's durability under stress.

Spurred by the same analysis as Hardy and colleagues, Bright and Freedman (1998) also performed a similar golf putting experiment that once again included the AST and non-AST implicit groups. Unlike Hardy, however, their results demonstrated that the implicit group, with the AST during the stress condition, demonstrated the same performance changes as that of the explicit group. This signaled that the performance increase of the implicit group without the AST in the stress phase was simply the result of the dual task removal, rather than any inherent shield against stress by implicit learning. As a result of their findings, there seems to be equivocal results with respect to the effect of stress on implicit and explicit based performance of motor skill.

The implications of this line of research are very important and have the possibility for widespread application in the future. The fact that there is equivocal data in this area leaves this issue ripe for further analysis and applications to more diversified fields. The present experiment attempted to expand on this research and examine the influence of implicit/explicit paradigm on the more dynamic, complex, and cognitive task of controlling a flight simulation. Several issues resulting from these studies will now be addressed in preparation for the current study.

Considerations for Future Study

One of the arguments against the use of testing using AST has been the lack of evidence that such patterns or processes of learning would ever take place in the real world. To the contrary, while it is quite logical that a random letter generation task would never be used in real life, it is easy to make the extrapolation that this secondary task could exist in another form. A relevant practical example of a task that would consume cognitive resources while flying a plane would be having to make proper radio calls, or having to check for air traffic, and the like. Thus, from a pragmatic standpoint, there are a number of avenues for future research, not only in the application of implicit and explicit based research, but also with regard to general study of resource constraints and workload and their affect on residual attention and perception (see Curry, Kleinman, & Hoffman, 1977; Damos, 1978).

It is possible that individuals exposed to explicit learning can achieve a higher level of average performance, such that the decrease in performance due to stress would still outperform any purely implicitly based task. Broadbent, FitzGerald, and Broadbent (1986) noted, for example, that performance changes may occur without an increase in verbal knowledge, but when verbal knowledge increases, performance always changes. Thus, verbal knowledge is inherently associated with increased performance. In the study by Masters (1992), and Hardy et al. (1996), the explicit group always achieved a higher level of performance, and though decreases in performance were seen under stress, their performance was still above that of the implicit group. The implication of this fact makes it difficult to make an analysis as to the importance of any decrease in explicit performance that has been noticed.

Added Dimensions for Study

Seger (1994) included as a criteria for implicit learning that information being learned must be complex, since simple patterns lend themselves to explicit learning. The most important aspect that determines complexity of a task is the number of rules that must be learned. It is quite possible that the task of putting is so simple of a task that a useful analysis of implicit learning cannot be achieved. Of course this statement cannot be assumed to be true, but it can be argued that a golf putt constitutes what would be considered a simple task with few rules. Masters (1992) described the golf-putting task as a complex motor skill, however it is clear that there is little cognitive skill involved with a golf putt and would be considered a relatively simple motion when compared to the full body mechanics involved with other sports. Another factor that leads to complexity is the number of variables to be processed. According to Broadbent et al. (1986), implicit learning involves the processing of more variables than does explicit. With golf putting being a relatively closed task, perhaps more open sport applications with more variables may not apply to the results established by the current line of study.

Berry and Broadbent (1988) found that when the relationship between input variables and output was simpler and more obvious, then tasks were performed in a more conscious explicit manner. Perhaps the simplicity of a putting task prompted this decrease in performance because it is geared for an explicit state. In the current investigation, the relative merits of implicit and explicit learning for a complex task were evaluated to determine their respective influences on the general learning process and performance under stress.

Another area of interest is the difference between explicit knowledge provided initially versus explicit knowledge gained through experience. Masters (1992), Hardy, et al. (1996), and Bright and Freedman (1998) all established the ability of control group participants to obtain explicit knowledge over time, although they knew nothing before testing. Similarly, it can be concluded that those who receive explicit knowledge before practicing the task also acquire additional rules through experience. In this study a group was added that received the explicit knowledge before performance, but performed the AST during practice, preventing further conditioning of its explicit knowledge base. This allowed a comparison of performance between explicit knowledge provided and self-generated explicit knowledge gained through practice.

Relationship Between Explicit and Implicit Learning

There continues to be debate concerning almost every aspect of implicit and explicit learning. One of the main problems is the inability to fully divide each type of learning as it is currently defined and understood. In an applied setting, it would almost seem impossible to achieve a task that was purely learned based on either implicit or explicit learning. Seger (1994) made the observation that most environments one encounters discourage any type of implicit learning, or at least favor explicit. Individuals are always compared to set standards or way of doing things, or are expected to justify their actions according to explicit knowledge references. It may be possible to emphasize implicit or explicit learning, but to isolate tasks with applied implications that only focus on one type of learning is perhaps impossible.

The underlying purpose of this study therefore, is not to make a distinction between each type of learning or to make a judgment as to which model should be emphasized for learning, but rather to delineate the attributes and performance implications for both implicit-explicit paradigms in an attempt to make suggestions for possible improvements in general learning strategies. The reality is that this realm of research is still in its infancy. The present investigation continued the investigation of implicit and explicit learning by demonstrating the effect each has on skill acquisition of a complex, cognitive task, which until now has not been explored. Additionally, the present study integrated resulting performance information with data from eye tracking analysis to provide the added association of these issues with attentional focus. Both of these additions provided a useful contribution to this emerging realm of cognitive research.

CHAPTER 3
METHOD

Participants

Participants were selected from undergraduate courses in the department of Exercise and Sport Science as well as from members of the Air Force, Army, and Navy ROTC detachments at the University of Florida. Initially 118 men and women expressed interest in participation in the study. In order to fully examine the affect of learning strategies on performance, only participants with little knowledge of the flying task being performed were used. All participants therefore completed a questionnaire prior to testing to ensure that they met these requirements (see Appendix A). Participants for the study were selected from the remaining pool of qualified volunteers that had little or no flight experience, and minimal knowledge of flight dynamic principles. Ultimately, 50 participants (25 male, 25 female) between the ages of 18 and 33 with a mean $\underline{M} = 20.54$, $\underline{SD} = 2.94$ were included in the study. Each participant was randomly assigned to one of five test conditions: control (C), non-stress control (NSC), implicit learning (IL), explicit learning (EL), and explicit learning control (ELC). Each group contained both five males and five females.

Apparatus & Task

Three segments of testing were completed consisting of two main tasks: a flight simulation and a data extraction task. During performance of the flight simulation task, eye movements to particular areas of interest were recorded as well as measurements of physiological arousal and cognitive anxiety.

Flight Simulator

The software used for the flight simulation was the Microsoft Flight Simulator 2000: Professional Edition (Seattle, WA). For the purpose of this study, the Cessna 182S was the plane used during simulation because of its relatively simple instrument display layout. The simulation was run on a ProStar 8290K IBM-compatible PII-366 computer (City of Industry, CA), and was controlled using the Logitech WingMan Extreme Digital 3D joystick (Model #J-ZA10, Fremont, CA). A Sharp Liquid Crystal Display Video Projection unit (Model #XG-NV2U, Camas, WA) was used to project the cockpit image onto a large projection screen.

Data Extraction Task

The extraction task consisted of a presentation of ten slides depicting the simulator instrument panel in different flight situations. Each slide contained various aircraft positions with a unique combination of airspeed, altitude, and heading. The participants were asked to provide the exact airspeed, altitude, and heading for each of the ten slides. The amount of time that it took for this data extraction to occur was recorded through use of a Campbell Scientific CR23X Micro logger. Slides were projected using a Kodak Ektagraphic III AMT slide projector (Rochester, NY). Slides were controlled by each participant through use of a remote control that was connected to the projector.

Eye Tracking

An Applied Science Laboratories (ASL, Waltham, MA) 5000 eye tracker, in coordination with a Magnetic Head Tracking system (Ascension Technologies, Flock of Birds, Burlington, VT) was used to collect gaze pattern information from each participant.

The system used a near-infrared illumination beam that illuminated the pupil of each participant. A camera mounted on the visor detected the pupil center and corneal reflection from this beam. The eye tracker then measured the difference between these two points. This information was integrated with the head tracker information, which used a visor-mounted sensor to simultaneously track the position of the head in space. This allowed for head movement during testing while still maintaining an accurate line of sight measurement.

Individual calibration done at the beginning of participant testing established a relationship between this data and the eye line of sight for each participant. The accompanying ASL eye analysis software was then used to compare eye line of sight calculations to a predefined area of interest file that allowed the program to determine where the ten areas described above were located on the projection screen. Accordingly, the point of gaze for each participant with respect to the screen and each respective instrument could be determined.

Metronome & AST

Examination of implicit learning required the prevention of explicit knowledge acquisition for several testing groups. To accomplish this, participants were required to perform a secondary task while flying called the Articulatory Suppression Task (AST), which involved the generation of random letters by each participant at designated intervals. A Franz (New Haven, CN) electronic metronome was used to emit clicks every 1 s or 1.5 s, depending on the test session. Participants who performed this task were required to verbally say a random letter each time a click was heard from the metronome.

Arousal

Physiological arousal was measured through use of a Polar (Model Vantage NV, Woodbury, NY) heart rate monitor (HRM) and associated Polar Advantage Interface System. The HRM included two parts: a transmitter and a receiver. The transmitter consisted of a flat band with two electrode surfaces that were placed around the participant's chest and was held in place by an adjustable elastic band that attached the two sides of the transmitter band together. The receiver was a watch that each participant wore during testing. The watch received a signal from the transmitter that enabled it to record the heart rate of the participant during testing. Data from the watch was then downloaded to the Polar Advantage Interface System after each session, which provided the heart rate (HR).

Anxiety

The Competitive State Anxiety Inventory-2 (Martens, Burton, Vealey, Bump, & Smith, 1990) was administered as a measure of performance anxiety (see Appendix B). The CSAI-2 is a state measure of anxiety requiring participants to self-report levels of temporary anxiety evoked by the test. Three subscales were analyzed including cognitive anxiety, somatic anxiety, and self-confidence. Each subscale consisted of 9 questions for a total of 27 questions. Responses for each item were scored using a 4-point Likert scale ranging from "Not at all" to "Very much so." Also included with each question of the CSAI-2 was a corresponding 7-point Likert scale to measure if the statement in question was either facilitative of debilitative to a participant's perceived performance ability. Reliability, internal consistency, and concurrent validity of the CSAI-2 have been well established by prior research.

Procedure

At the beginning of testing, participants were informed that the general purpose of the experiment was to examine their visual search patterns as well as their performance on a flight simulation task during different conditions. They were then asked to read and sign an informed consent (see Appendix C). Any questions they had about the experiment were answered at that time. All participants were tested individually. All performance task instructions were directly read from prepared instructions to eliminate variability in information presentation (see Appendix D).

Heart Rate

The sympathetic activation resulting from the increased arousal during the stress condition could have generated many possible symptoms including pupil dilation, tachycardia, increased blood pressure, increased respiratory rate, and increased sweating, as well as associated factors such as increased muscle tension (Abernethy, 1993). For the purpose of this study and as a means of comparison with previous research in this area, heart rate was recorded as the measure of arousal. At the beginning of every test session, each participant was fitted with the HRM and was required to sit quietly for five minutes to reduce his/her HR to baseline levels. Heart rate was then recorded for three minutes prior to testing. During the stress condition, an additional heart rate measurement was taken after the stress manipulation was provided, in order to serve as an indicator of the induced physiological arousal mentioned above.

Scanning Pattern

After the HR was taken for each test session, each participant was seated in front of the projection screen and fitted with the ASL 5000 eye tracker. Calibration was then performed for each participant that consisted of fixation by the participant on nine points of known locations with respect to the scene camera. Eye movements were recorded for all flying tasks in an "eye head" data file and stored for analysis.

Flying Performance

There were two flying tasks used during the experiment. The first test was used to represent performance of a complex task. Each participant flew for seven minutes on the flight simulator. They were provided with a desired heading (60 degrees), speed (100 knots), and altitude (3000 feet) to maintain. The simulation began close to these established values and the participants were asked to continue to fly the aircraft as close to these desired levels as possible for the entire duration of the task. For each flying task, the participants had the ability to control the simulation through use of the Logitech Wingman joystick. It allowed for the control of horizontal and vertical movement using the handle as well as thrust adjustment through use of a side lever. The second task was used to represent performance of a simple task. Each participant continued with another 7-minute flight, however, during this segment, they were only required to maintain the proper 3000-foot altitude. For both tasks, the projected scenery display consisted of overcast skies to minimize reliance on orientation information other than that provided by the instruments.

Data Extraction

The final segment did not require the use of the flight simulator or the eye tracker. The purpose of the final segment was to determine the speed and accuracy of each participant's ability to read information from the instrument panel. During this segment the participant viewed 10 slides of scenes taken directly from the simulator. The same 10 slides were used for each test session but the order of presentation was randomized prior to each test session using a table of random numbers. The participants were required to verbally say the heading, speed, and altitude of the aircraft for each situation when it was viewed. The main investigator recorded these values for all 10 slides on a prepared data sheet (see Appendix E).

To begin, each participant was placed in front of the projection screen and was given a remote control button for the slide projector. The participant was instructed to push the control button, which would advance the slide projector to the first slide and start a timer on the micro logger. They were told that once they had stated the necessary information, they should press the button again, which would advance the projector to a blank slide and stop the timer. It was explained that this process would continue for all 10 slides. Both speed and accuracy was emphasized.

State Anxiety

The Competitive State Anxiety Inventory-2 (Martens, Burton, Vealey, Bump, & Smith, 1990) was provided to each participant to fill out during the inter-flight phases of the second and fifth test blocks to assess his/her state anxiety. The assessment from the second session served as a baseline for comparison to the evaluation during the fifth session where the anxiety manipulation was evoked.

Test Sessions

Each test session consisted of three counterbalanced segments, which included one 7-minute complex task, one 7-minute simple task, and the data extraction task. There were a total of six test blocks used for this experiment. The first test block consisted of a standardized pre-test that was used to provide a consistent pre-manipulation baseline performance for each respective group. This was followed by three skill acquisition phases where each group continued to improve their performance. The fifth test block contained the induced stress manipulation. The final test block was a retention test to gauge the amount of learning that had occurred during the experiment.

The testing for each subject took place over four days. The pre-test and first skill acquisition block was on the first day of testing. The final two acquisition trials took place on the second day. The stress manipulation was made on the third day. Finally, the retention test took place on the fourth day. Each block trial will now be explained in further detail.

Pre-test

All participants performed the pre-test with the AST (described later) in order to prevent the implicit groups from obtaining explicit knowledge of the simulation, as well as to provide consistent conditions for assessing baseline performance for all participants before experimental manipulations.

Skill acquisition

After the pretest, specific instructions designed for each testing condition were provided. While waiting for the baseline heart measurement in the second test session, the EL group reviewed instructions with specific information needed to fly the aircraft.

The information provided included a familiarization with use of the joystick and throttle in controlling and maneuvering the aircraft, as well as an introduction to the cockpit to include an explanation of the use, interpretation, and association of the key instruments needed for the simulation (see Appendix E). Participants were instructed to utilize this information while flying the simulator. Information was reviewed before each of the final two test sessions during the resting period before baseline HRM.

The IL group did not receive any information about the simulation before testing. As described earlier, to prevent the acquisition of explicit knowledge about the task, this group was required to perform the AST random letter generation task while flying. The clicks initially sounded at a rate of every 1.5 s. As per Masters (1992), the clicks increased in frequency to one every second for the final test session in order to maintain the difficulty of the secondary task. Participants were instructed to continue letter generation throughout the duration of each flight simulation task, and that they should keep the letters as random as possible. Similar to the EL group, these instructions were reviewed during the 5-minute resting period before the final two test sessions.

The ELC group was a combination of both the EL and IL groups. Similar to the EL group, they received training on aircraft control and instrumentation before block two, but like the IL group they were also required to perform the AST during the remaining five test sessions so as to prevent this group from acquiring self-developed explicit knowledge during testing. The manipulation allowed comparison to the EL group and the control group to establish the differences between taught and self-generated explicit knowledge in relation to performance.

Finally, there were two control groups used for baseline analysis. The C group was not provided with information nor were they required to perform an AST. They were simply told to improve as much as possible during the simulation. To maintain consistency with prior literature (e.g., Masters 1992 and Hardy et al. 1996) a NSC group was included which was not stressed during the final test session. This group was used to determine whether performance would have continued to improve through the stress test session or whether it had reached asymptote.

Stress manipulation

To induce the anxiety response during the fifth session, the EL, ELC, C, and IL groups were placed in a state of heightened anxiety through the combination of (1) videotape recording their performance and (2) a financial incentive based upon performance consisting of a cash prizes of $50, $30, or $20, for first, second, and third place respectively. This information was provided through a standardized statement explaining the need for high performance in the final session in order to receive the cash reward (see Appendix F). Each participant was told that based upon their practice sessions they would be in position to win the money and that their performance on the final test session would determine whether they received it or not. They were also told that their performance would be taped for possible inclusion in a video made for Television. This information was explained during the HR monitoring period before testing. Physiological arousal response to these factors was then determined by comparing the baseline HR to their HR after this information was provided.

Retention

The retention test block was performed 120 hours after the stressed block, and was used to determine how well each group performed to check the amount of learning that had occurred for each group during testing. The retention task included only half of the testing subjects with 5 per group for a total of 25. The retention test also only included the complex flying task, leaving out the simple task segment and the data extraction task.

Explicit Knowledge Check

Upon completion of the stress test session, all participants were asked to write down every factor that they had learned, used to help control the airplane, or used to read the instrument panel during the experiment as an index of the amount of explicit knowledge that was gained by each group. A standardized set of instructions was read informing the participant to include things such as control of the airplane, reading or interpreting the instrumentation, the relation between instruments, or factors in aircraft performance (see Appendix G). As with prior research in this area, an explicit rule was considered one that was either received through training or one that pertained to a technical aspect of the instruments or aircraft control.

Manipulation Check

As verification of how effective testing procedures were for each group, a post-experiment questionnaire was filled out by each participant before debriefing (see Appendix H). Items included an assessment of their perceived attention patterns during flight, their belief of the stress manipulation, and their characteristic level of anxiety during competitive situations. Any comments that a participant had about the experiment were taken at this time as well.

Debriefing

During and after testing, it was stressed that the study was ongoing, and that it was important that the experimental procedures were not shared with anyone else, whether they had been involved with the experiment or not. Upon completion of the study, each participant was debriefed on the specific manipulations used in the experiment as well as the underlying purpose of the study (see Appendix I). The cash prizes were awarded based on the best performances on the initial standardized pre-test.

CHAPTER 4
RESULTS

Results were calculated for the stress manipulation, explicit knowledge generated, slide information extraction, group performance, and scanning pattern utilizing the established procedures. The important trends and significant results noticed from the analyzed data with respect to corresponding hypotheses will now be discussed.

Amount of Explicit Knowledge

The number of explicit rules provided by each participant after testing was used as a measure of the amount of explicit knowledge acquired. As mentioned before each piece of information provided was considered an explicit rule if it was either an item received through training or any other rule that pertained to a technical aspect of the instruments or aircraft control. The rules provided by each participant were divided into three categories including general, control, and interaction. The general category included any generic information such as what information each instrument provided or how to read each instrument. The control category included any statements made referencing how the joystick or thrust was used to control the aircraft to keep the instruments within the proper parameters. The interaction category included any information detailing the interactions that exist between instruments that would lead to superior control of any of the flight axis. The mean number of rules for each category and the total combined rules generated by each group is found in Table 1.

Table 1. Mean explicit rules generated

	Total	General	Control	Interaction
Explicit	11.00	6.30	2.60	2.10
Exp Con	10.40	6.00	2.10	2.30
Control	8.70	5.40	2.40	0.90
NSC	8.80	5.40	1.60	1.80
Implicit	4.60	3.60	0.20	0.70

To establish if there was a significant difference in the amount of explicit knowledge provided by each group, a one-way ANOVA was conducted on the group means for total rules generated. Results revealed a significant group main effect, $\underline{F}$ (4, 45) = 8.61, $\underline{p}$ < .001. Post hoc comparison using Tukey's analysis provided support for the hypothesis by finding that the implicit group's mean was significantly lower than all four of the other groups. There were no other significant differences between groups.

Stress Manipulation

In order to determine the effect of the stress manipulation, HR was recorded to evaluate physiological arousal. The CSAI-2 was also provided to determine the somatic and cognitive anxiety changes associated with the stress manipulation.

Heart Rate

HR values from the Polar Advantage Interface System were recorded for each test session and the resulting changes from the stress intervention were analyzed using a 5 X 2 (Group X Session) mixed design ANOVA with repeated measures on the second factor. The results demonstrated a significant session main effect, $\underline{F}$ (1, 45) = 18.16, $\underline{p}$ < .001, with a significantly higher HR after the stress manipulation (see Table 2). The displayed values are for resting HR as well as the HR taken after the anxiety manipulation was introduced in the fifth test session. All four groups that experienced the stress manipulation had an increase in heart rate. The decrease in the NSC group was noted by the session-group interaction, which neared significance, F (4, 45) = 2.37, $p >$ .067.

Table 2. Mean and standard deviation (SD) for heart rate before and after stress manipulation

	Stress Manipulatio			
	Befor		After	
	Mean	SD	Mean	SD
Explicit	74.9	(7.4)	79.7	(12.2)
Exp Con	75.8	(11.1)	80.3	(12.6)
Control	77.7	(10.6)	83.1	(12.2)
NSC	81.6	(13.3)	80.0	(16.4)
Implicit	74.0	(12.1)	79.8	(12.8)

Anxiety

The anxiety component subscales of the CSAI-2 (cognitive anxiety, somatic anxiety) were totaled for each participant and averaged for each group. Results in Figures 1 & 2 below illustrate an increase in both cognitive and somatic anxiety during the stress condition for all four groups that received the treatment.

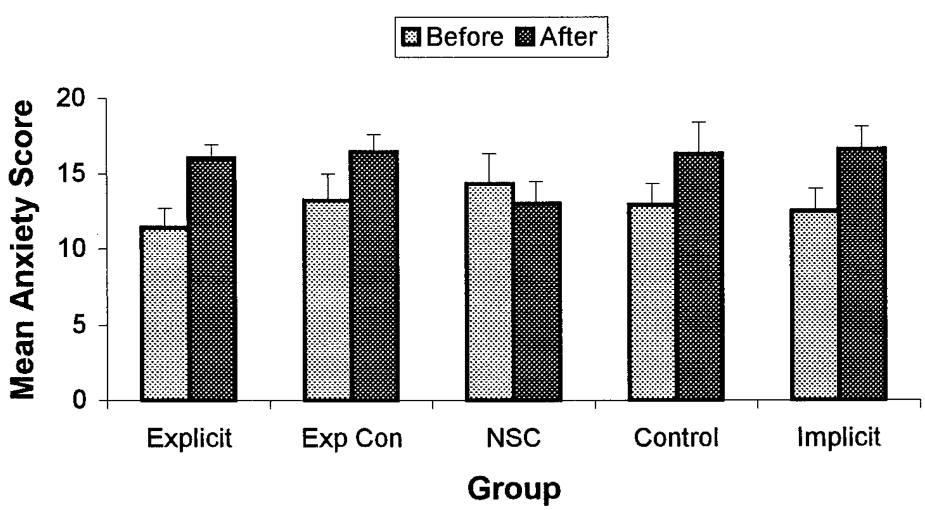


Figure 1. Mean and SD of reported CSAI-2 cognitive anxiety levels before and after stress

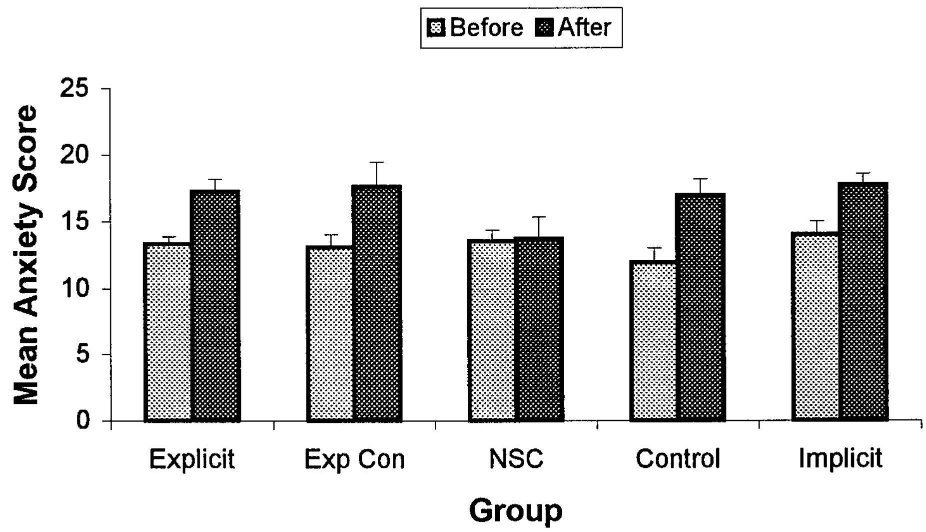


Figure 2. Mean and SD of reported CSAI-2 somatic anxiety levels before and after stress

Group differences for each anxiety level were analyzed through use of separate 5 X 2 (Group X Session) mixed design ANOVA's with repeated measures on the second factor. Analysis revealed a significant session main effect for both cognitive anxiety, F (1, 45) = 35.75, $p < .001$, and somatic anxiety, F (1, 45) = 50.72, $p < .001$. A significant group by session interaction was found for both cognitive anxiety, F (4, 45) = 5.08, $p < .01$, and somatic anxiety, F (4, 45) = 3.04, $p < .05$ as well. Simple effect tests for both cognitive and somatic anxiety similarly revealed that the NSC was the only group to not demonstrate an increase after stress.

Because of the significant findings mentioned above, the results of the post experiment questionnaire, which was used as a manipulation check, were not analyzed. The data (see Table 3), however, revealed similar group results for belief in the stress manipulations.

Table 3. Means of post-experiment questionnaire answers

	1 - Not at all			7 - Very much so	
	Explicit	Exp Con	Control	NSC	Implicit
Simulation lifelike?	4.3	4.3	3.7	4.7	4.2
Attention (0 = Letter, 7 = Flying)	4.6	4.6	4.3	3.5	5.0
Did letters affect performance?	4.7	4.7	5.6	5.7	4.4
Did you believe the video?	5.2	5.6	5.1	N/A	5.5
Did you believe the $50?	6.6	6.7	6.2	5.6	6.5
Did you believe the graph?	5.9	5.9	6.3	N/A	5.6
Competition affect anxiety, confidence?	3.7	4.7	3.5	3.8	4.6
Do you feel anxious during competition?	2.9	4.4	3.9	5.0	4.3

Group Performance Changes

Deviations from the predetermined levels for heading, speed, and altitude were used as the dependent variables for flight performance during both complex and simple segments. These deviations were calculated after each test session by sampling the instrument readings at 10-second intervals. Review of this information was based on a flight video that was recorded for each test session by the flight simulator. Flight performance for each group was calculated as a root mean square (RMS) error for airspeed, altitude, and heading maintained during flight. RMS error is a calculation of total error that takes into account the accuracy and variability of each performance and was determined based on the deviation of each group from the established values mentioned in the previous chapter. A smaller RMS value represents increased performance and a smaller error.

Airspeed

It was hypothesized that a characteristic reduction in error for airspeed, altitude, and heading control would exist for all groups during testing. The data from experimentation demonstrated a characteristic reduction in RMS error over subsequent trials for each variable (see Figures 3, 5, & 6).

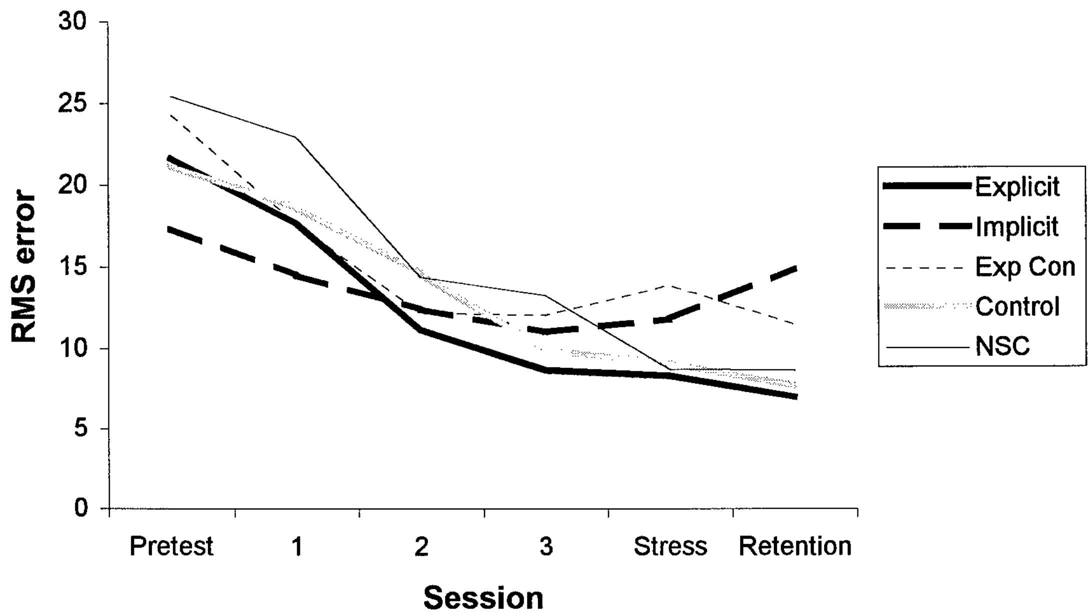


Figure 3. Airspeed error: complex task

Analysis for performance differences in airspeed was calculated through use of a 5 X 5 (Group X Session) mixed design ANOVA with repeated measures on the second factor. Results of the ANOVA revealed a significant session performance decrease, $\underline{F}$ (1, 45) = 74.11, $\underline{p} < .001$. Pairwise comparison demonstrated a significant decrease in error through the third acquisition trial. No group differences were found $\underline{F}$ (4, 45) = 1.83, $\underline{p} >$ .05.

One other aspect of the airspeed results that should be noted was the relatively low initial error that the implicit group displayed as compared to the rest of the groups. Because of this superior performance by the implicit group, the group's differences are not as profound as perhaps they would have been if the groups were initially equal. In an attempt to demonstrate a more realistic difference in improvement explicit knowledge provided over time, the percent improvement of all groups during each test session with respect to each group's initial performance values was graphed (Figure 4). From this plot it can clearly be seen that the implicit group performance improvement over the trials was relatively lower in comparison to all other groups. It should be taken into consideration that there might be some floor effects for implicit performance that would affect the curve. As detailed in Figure 3, however, the explicit group did have a lower error than the implicit group after the first acquisition trial, so it was still possible for the implicit group to improve. Despite the lack of significant group effects, there is still some support for the notion that explicit knowledge was beneficial for the retention session.

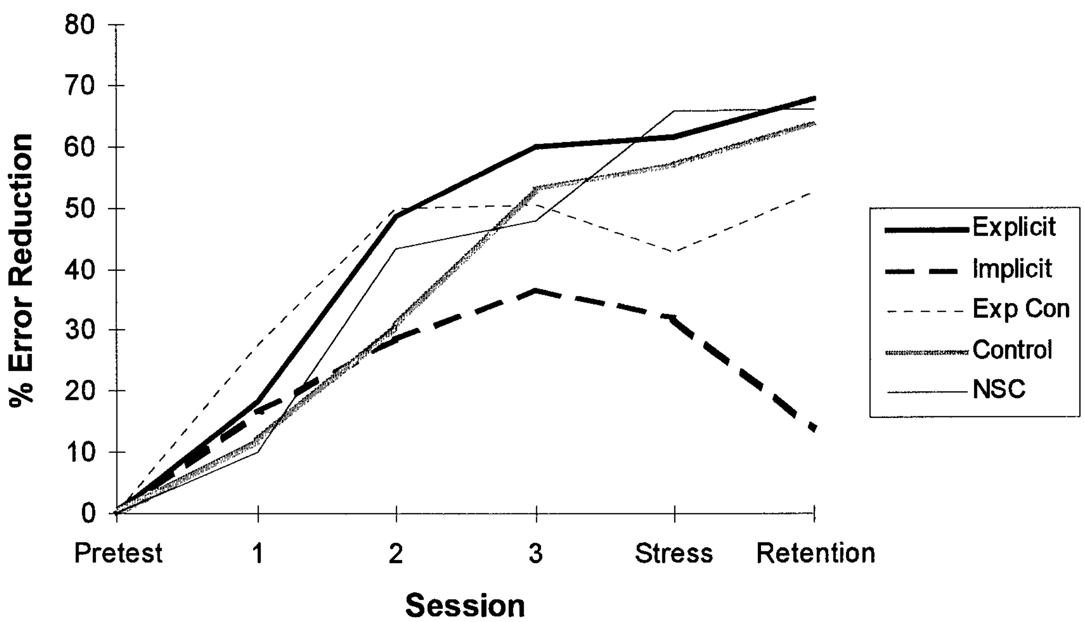


Figure 4. Percent error reduction of each session with respect to Session 1 group performance

To determine if the elevated implicit pretest performance created a significant difference, a 5 X 5 (Group X Session) mixed design ANCOVA with repeated measures on the second factor was used to account for initial performance differences between groups. The initial pretest performance scores were used as the covariate for the ANCOVA calculation. Analysis revealed a significant session main effect, $\underline{F}$ (1, 45) = 6.17, $\underline{p} < .05$. More importantly, a session by group interaction was also revealed, $\underline{F}$ (4, 45) = 3.52, $\underline{p} < .05$. Simple effect testing revealed a significant group difference for the stress phase, $\underline{F}$ (4, 45) = 2.60, $\underline{p} < .05$. Despite overall significance for the stress condition, further analysis by Tukey's HSD did not delineate any significant group differences. The implicit group performed worse during the retention trial as compared to their previous error levels and as compared to the rest of the groups. Despite this trend, effects test analysis revealed that the difference for the retention phase approached, but did not reach significance, $\underline{F}$ (4, 20) = 2.65, $\underline{p} > .063$.

Heading

Analysis for performance differences in heading was also calculated with a 5 X 5 (Group X Session) mixed design ANOVA with repeated measures on the second factor.

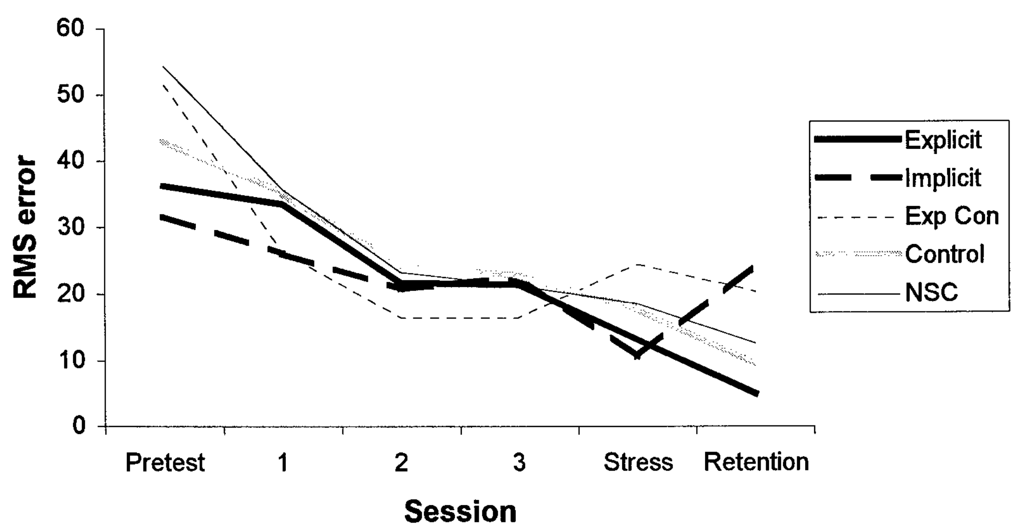


Figure 5. Heading error: complex task

A significant session main effect emerged, $F(1, 45) = 26.83$, $p < .001$. Pairwise comparison confirmed a significant decrease in error through the first three sessions. No group differences were found $F(4, 45) = .24$, $p > .05$. A one way ANOVA to detect group differences for the retention session, revealed a significant group difference, $F(4, 20) = 5.09$, $p < .01$. Post hoc analysis using Tukey's HSD indicated significantly worse performance for the implicit group as compared to that of both the explicit ($p < .01$), and control ($p < .05$) groups.

Altitude

Data analysis for altitude contained a third variable (difficulty), because the altitude was maintained in both the difficult and simple task segments. Altitude was

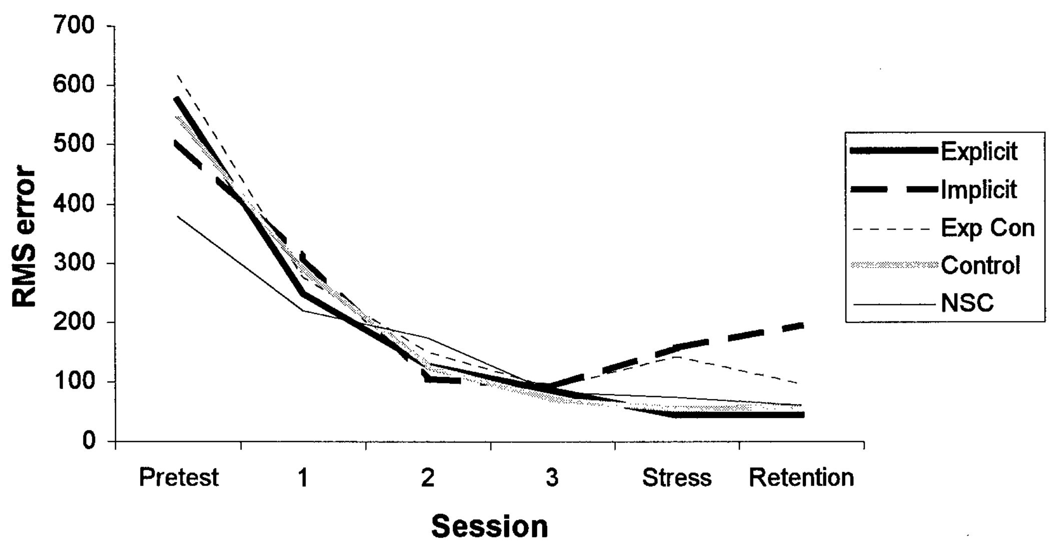


Figure 6. Altitude error: complex task

therefore analyzed using a 5 X 2 X 5 (Group X Difficulty X Session) mixed design ANOVA with repeated measures on the second and last factors. Results of the ANOVA for altitude control revealed a significant session main effect, $F(1, 45) = 74.94$, $p < .001$, as well as a significant difficulty main effect, F (1, 45) = 5.95, $p < .05$. Pairwise comparison demonstrated a significant decrease in error through the third acquisition trial, similar to the airspeed, and a significantly lower error during the simple task. No overall group differences were found from the pretest to stress phase, F (4, 45) = .44, $p > .05$. A one way ANOVA to detect group differences for the retention session revealed a significant group difference, F (4, 20) = 5.48, $p < .01$. Results of Tukey's HSD revealed that the implicit group performed significantly worse then every group except the explicit control group.

Variability in Scanning Pattern

Eye line of sight data was used to determine the total number of fixations, the total length of fixations, mean durations of fixation for each instrument, as well as the search rate for each participant. Dividing the total fixation duration for each participant by the total number of fixations generated the search rate. The visual field for the participant was divided into ten main areas: the Airspeed Indicator (ASI), the Vertical Speed Indicator (VSI), the altimeter (Alt), the Attitude Indicator, Heading Indicator, the visual field from the cockpit window, and three areas of non-essential instruments labeled as "other (1-3)".

Search Rate

It was hypothesized that the explicit groups would have faster search rates, as compared to the implicit groups. A 5 X 2 X 5 (Group X Difficulty X Session) mixed design ANOVA with repeated measures on the last two factors was used to analyze the resulting search rate differences (Table 3). The results found no group differences, F (4, 45) = .40, $p > .05$. A significant difference in search rate however was found between task complexities, F (1, 45) = 50.90, p < .001. The search rate during the simple task was significantly lower that the complex task. This was expected because the participants had fewer variables and instruments from which they needed to scan, resulting in a slower search rate.

Table 4. Search rate mean and standard deviation (SD) for each group

	Pretest		Acq. 1		Acq. 2	
	Complex	Simple	Complex	Simple	Complex	Simple
Explicit	2.52 (.75)	1.88 (.49)	2.02 (.58	1.87 (.68)	1.65 (.29)	1.60 (.42)
Exp Con	2.24 (.74)	1.90 (.40)	2.09 (.51	1.74 (.58)	2.03 (.53)	1.96 (.93)
Control	2.08 (.89)	1.66 (.89)	1.86 (.78	1.63 (.77)	1.76 (.63)	1.45 (.87)
NSC	1.88 (.40)	1.76 (.64)	2.14 (.58	1.60 (.70)	1.96 (.44)	1.53 (.53)
Implicit	2.24 (1.09)	2.06 (.83)	2.25 (.94	1.70 (.84)	2.11 (.83)	1.79 (1.13)

	Acq. 3		Stress		Retention
	Complex	Simple	Complex	Simple	Complex
Explicit	1.87 (.47)	1.80 (.99)	1.84 (.61	1.81 (.79)	1.55 (.31)
Exp Con	1.98 (.88)	1.94 (1.30)	2.08 (.65	1.61 (.78)	1.96 (.28)
Control	1.90 (.93)	1.51 (.98)	2.04 (.77	1.81 (.86)	1.83 (.37)
NSC	1.88 (.45)	1.62 (.64)	1.77 (.52	1.53 (.61)	1.43 (.29)
Implicit	2.20 (1.01)	1.83 (1.21)	2.13 (1.08	1.72 (1.05)	1.90 (1.05)

Number of Fixations

Unlike search rate, which was an instrument independent parameter, analysis for the number of fixations was completed with a separate 5 X 2 X 5 (Group X Difficulty X Session) mixed design ANOVA with repeated measures on the last two factors for each respective instrument of interest. Analysis was conducted for three instruments (altimeter, attitude directional indicator, and vertical velocity indicator), which have been used in previous research to differentiate novice from expert scanning patterns (see Bellenkes et al. 1997). The ADI provides integrated information for control of both heading and altitude and constitutes a greater proportion of fixations for experts.

Similarly, the VSI provides more specific information for maintaining altitude, and would be fixated on more by experts. The number of fixations on each instrument for every group during the complex task is displayed in Figure 7, and for the simple task in Figure 8.

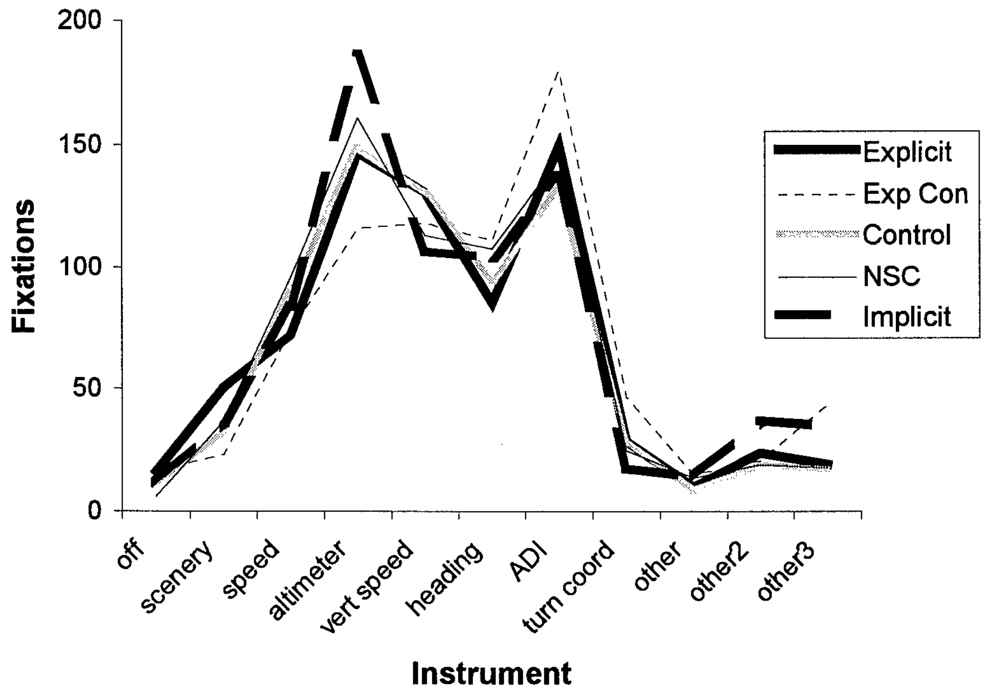


Figure 7. Mean fixations on each instrument: complex task

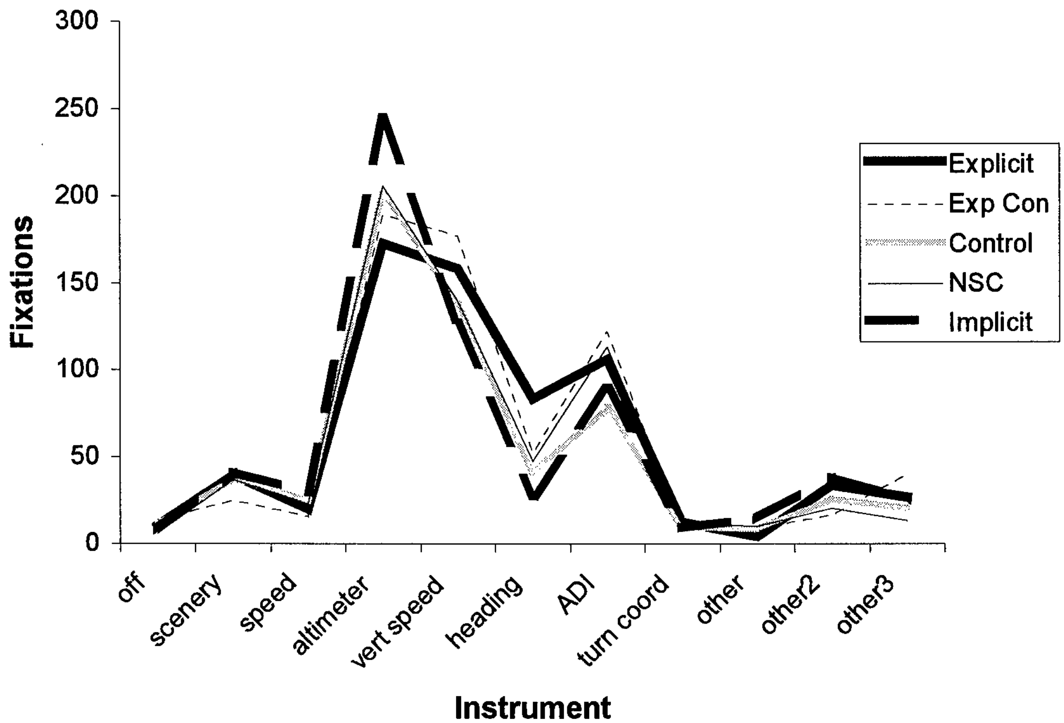


Figure 8. Mean fixations on each instrument: simple task

<u>ADI</u>

There were no group differences for fixations on the ADI, $\underline{F}$ (4, 45) = .63, $\underline{p} > .05$. The only significant findings for fixations on the ADI revealed a significant decrease in fixations for the simple task, $\underline{F}$ (1, 45) = 30.33, $\underline{p} < .001$. Since the ADI provides information for multiple axes, this decrease could be expected for the simple task. Other instruments such as the altimeter or VSI could be used without loss of information.

Despite no group differences being found, there were several trends that should be addressed. For example, one would expect that there would be an increase in the ADI fixations for the explicit groups during the second test session after the knowledge was provided. Figure 9 is a graph of fixations on the ADI for each group across all sessions for the complex task. The number of fixations on the ADI dramatically increased after the explicit instructions were given. A 2 X 2 (Group X Session) mixed design ANOVA with repeated measures on the second factor revealed a significant increase in fixations on the ADI for the explicit and explicit control groups between these sessions, $F(1, 18) = 12.08$, $p < .01$. The trends for the simple task were similar and using the same analysis, also revealed a significant increase in fixations, $F(1, 18) = 6.54$, $p < .05$. There was a decrease that can be seen in the fixations over time as attention was gradually spread across other instruments. This decrease over time may have accounted for the insignificant overall findings mentioned above.

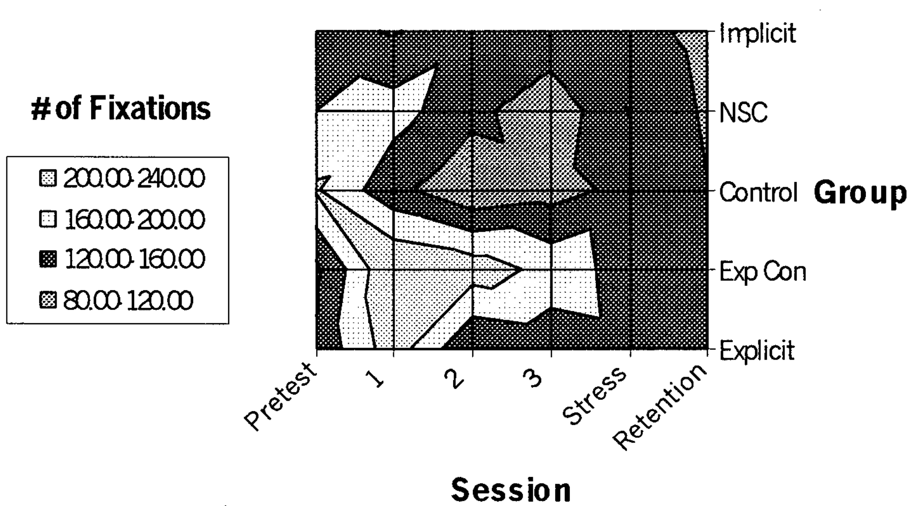


Figure 9. Mean fixations on the ADI: complex task

Altimeter

Despite the implicit group having more fixations on the altimeter (see Figure 8), there were no significant group differences observed, $F(4, 45) = 1.24$, $p > .05$. The only significant finding for fixations on the altimeter was a difficulty main effect. There was a significant increase in fixations for the simple task, $F(1, 45) = 34.22$, $p < .001$, which as mentioned before, could be expected since the only instrument changing for the simple task was the altitude.

Once again there were trends for the altimeter fixations that should be explained. Figure 10 below is in the same configuration as Figure 9 and depicts the fixations on the altimeter for all groups during each session. The implicit group has the most consistent use of the altimeter, and has an increased use of the altimeter during the retention period. The explicit groups on the other hand have the lowest use of the altimeter across all sessions. A one-way ANOVA conducted on the fixations during the retention phase revealed that the implicit group had significantly more fixations on the altimeter than the two explicit groups, $F(4, 20) = 3.43$, $p < .05$.

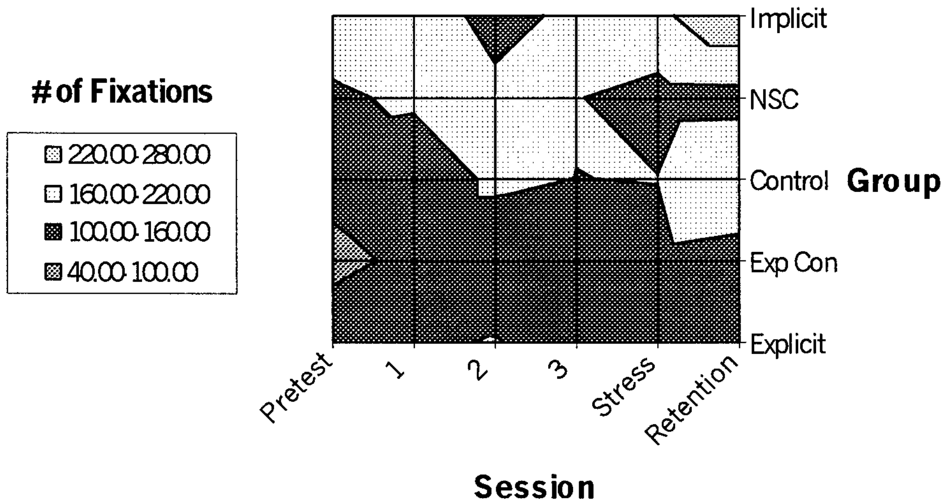


Figure 10. Mean fixations on the altimeter: complex task

<u>VSI</u>

Analysis for the VSI revealed a significant session and difficulty main effect. The number of fixations on the VSI increased significantly during the three skill acquisition phases, $F(1, 45) = 22.25$, $p < .001$. There also was a significant increase in fixations for the simple task, F (1, 45) = 20.32, p < .001. Like the altimeter, the observed increase in emphasis for this instrument over time could also be expected. No group differences for fixations on the VSI were found, F (4, 45) = .26, p > .05.

Average Fixation Duration

Analysis for average fixation duration was completed with separate 5 X 2 X 5 (Group X Difficulty X Session) mixed design ANOVA's with repeated measures on the last two factors for each respective instrument of interest. Analysis was conducted for the same three instruments: altimeter, attitude directional indicator, and vertical velocity indicator. Results for fixation duration followed much of the same patterns as the number of fixations. The instruments that were looked upon more often tended to have similar increases in fixation duration.

ADI

There were no significant main effect findings for the ADI including session, F (1, 45) = .001, p > .05, difficulty, F (1, 45) = 1.06, p > .05, and group, F (4, 45) = .32, p > .05.

Altimeter

The only significant main effect was for difficulty, F (1, 45) = 13.44, p < .001. There was no session, F (1, 45) = .08, p > .05, or group, F (1, 45) = .50, p > .05 main effect.

VSI

The same results were found as the fixations with a significant session and difficulty main effect. The fixation duration on the VSI increased significantly during the last two skill acquisition phases, F (1, 45) = 11.39, p < .01. There also was a significant increase in fixation duration for the simple task, $F(1, 45) = 17.81$, $p < .001$. No group main effect was observed, $F(4, 45) = .69$, $p > .05$.

Total Fixation Duration

Total fixation duration is a combination of the number of fixations and the average fixation duration, and represents the total time spent looking at each instrument during flight. Figure 11 below designates the total fixation duration in seconds on all 10 instruments for each group, averaged across all six sessions. It can be clearly seen that the two explicit groups spent most total time on the ADI, with the explicit group also better distributing their attentional focus to the VSI as well. The other three groups that did not receive instruction however, spent the higher proportion of time on the altimeter.

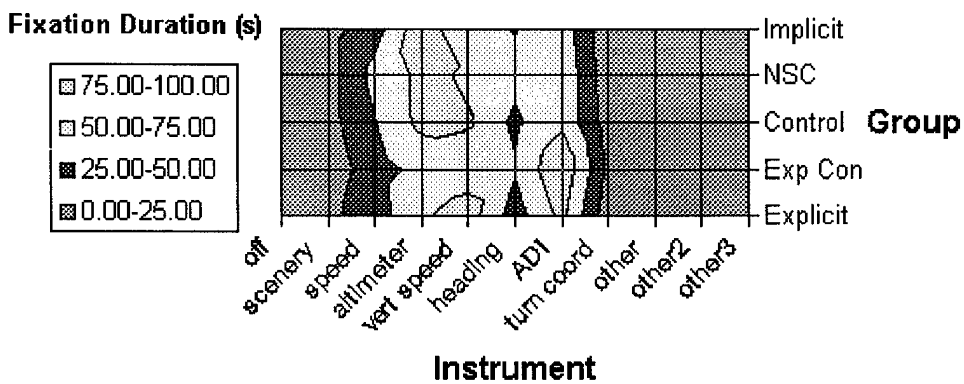


Figure 11. Total mean fixation duration

Analysis for total fixation duration was completed with separate 5 X 2 X 5 (Group X Difficulty X Session) mixed design ANOVA's with repeated measures on the last two factors for the altimeter, attitude directional indicator, and vertical velocity indicator.

ADI

Analysis revealed a significant main effect for difficulty, $F(1, 45) = 14.92$, $p < .001$, with a significant increase in total fixation duration for the complex task. There were no significant main effect findings for session, $\underline{F}$ (1, 45) = 1.72, $\underline{p} > .05$, or group, $\underline{F}$ (4, 45) = .49, $\underline{p} > .05$.

Altimeter

A significant session and difficulty main effect were found. The total fixation duration on the altimeter increased significantly only during the stress phase, $\underline{F}$ (1, 45) = 5.25, $\underline{p} < .001$. There was a significant increase in fixation duration for the simple task, $\underline{F}$ (1, 45) = 48.47, $\underline{p} < .001$. No group main effect was observed, $\underline{F}$ (4, 45) = 1.10, $\underline{p} > .05$.

VSI

A significant session and difficulty main effect were also found for total fixation duration on the VSI. The total fixation duration on the VSI increased significantly during the last two skill acquisition phases, $\underline{F}$ (1, 45) = 23.15, $\underline{p} < .001$. There also was a significant increase in fixation duration for the simple task, $\underline{F}$ (1, 45) = 32.96, $\underline{p} < .001$. No group main effect was observed, $\underline{F}$ (4, 45) = .56, $\underline{p} > .05$.

Information Extraction

Analysis for the information task was based on both speed and accuracy. Average slide task time for each session was recorded for each participant (Table 5). Average RMS error data extraction accuracy was also calculated for the accuracy of heading, speed, and altitude by comparing recorded values for each slide to the correct values (Table 6).

Table 5. Average time spent per slide

	Day 1	Day 2	Day 3
Explicit	39.57	22.69	18.05
Exp Con	32.69	22.37	18.30
NSC	42.21	29.07	23.38
Control	35.53	23.06	17.21
Implicit	33.48	23.09	17.97

Table 6. RMS error for data extraction of altitude, speed, and heading

	Day 1			Day 2			Day 3		
	Alt	Speed	Head	Alt	Speed	Head	Alt	Speed	Head
Explicit	1571.15	2.72	79.70	579.83	1.61	50.61	401.15	1.29	40.49
Exp Cont	1864.22	26.86	115.81	441.91	2.60	32.96	88.40	2.22	20.09
NSC	1912.52	16.56	90.93	629.54	1.96	83.94	583.72	1.44	75.94
Control	1755.65	4.53	86.52	458.30	5.25	81.18	301.59	2.16	63.09
Imp	2334.45	25.40	94.06	1399.01	2.40	79.12	545.36	2.02	61.08

Results for each variable were analyzed using a 5 x 3 (Group x Session) mixed design ANOVA with repeated measures on the second factor. Analysis for time used per slide, $\underline{F}$ (1, 45) = 154.08, $\underline{p} < .001$, response RMS for airspeed, $\underline{F}$ (1, 45) = 7.86, $\underline{p} < .01$, altitude, $\underline{F}$ (1, 45) = 88.32, $\underline{p} < .001$, and heading, $\underline{F}$ (1, 45) = 24.25, $\underline{p} < .001$ all produced significant session main effects across all three trials. While the explicit groups had lower RMS values in general, no group differences were revealed during the analysis.

CHAPTER 5
DISCUSSION

In the following chapter, significant results will be discussed in relation to both performance and attention control. The main focus will be to determine from the experiment results whether explicit knowledge is beneficial for more complex skills. In order to draw conclusions as to the effect of explicit and implicit learning on performance, the amount of explicit knowledge generated by each group will first be discussed. Next, the effectiveness of the stress manipulation will be evaluated. Finally analysis will be made for group performance, eye-tracking strategies, and data extraction to determine the role that explicit knowledge played in both performance during stress and for long-term retention.

Explicit Knowledge

It was hypothesized that the explicit group would be able to provide the most explicit rules after test completion, followed by the explicit control and control groups, then finally the implicit group. Results from the experiment confirmed this hypothesis, with the explicit group providing the most rules as expected, followed by the explicit control, the two control groups that exhibited nearly the same number of rules, and finally the implicit group, which generated the fewest rules.

It was also hypothesized that the implicit and control groups would not be able to provide information on flight dynamics or interactions. This was demonstrated in that the explicit and explicit control groups provided more average interaction rules. The implicit group also demonstrated a reduced number of control rules. The difference of the explicit groups from the control was not as large as what was expected, but the results nonetheless displayed the expected trend.

Despite the explicit groups supplying a significantly higher number of rules, the implicit group for this experiment produced an average of 4.6 rules. In a follow-up study to Masters' (1992) golf putting experiment, Maxwell, Masters, and Eves (2000) reviewed the recent studies in replication of Masters original golf task, and criticized the experimentation of Bright & Freedman (1998) because their implicit group had a high mean number of reported rules (3.5) as compared to the matching groups in the Masters study which had a mean of less than one rule. As a result of the high number of rules exhibited by the implicit learners, Maxwell and colleagues asserted that the analysis made by Bright and Freedman that implicit learners were not resistant to stress, was invalid. In refutation to this line of argumentation, there are several reasons why the 4.6 rules generated by the implicit group in this study should not prevent conclusions from being drawn from the data. First, the problem with this type of static rule comparison is that it is difficult, if not impossible, to know or compare the criteria each researcher used for inclusion as a rule. The present study was also a more complex system, which included three separate areas of explicit rules. Finally, the total number of explicit rules generated by this experiment at 11, was nearly twice the number presented in either of the other golf putting studies, which makes the number of implicit rules in this study seem rather reasonable.

Stress Manipulation

If the stress manipulation worked, one would expect an increase in heart rate to denote physiological arousal as well as an increase in cognitive and somatic anxiety from the CSAI-2. Results supported the effectiveness of the manipulation.

All four groups that were put under stress experienced relative heart rate increases, while the non-stress control group slightly reduced HR. The other important factor to note is that the established heart rate and standard deviations resulting from the study are similar to previous findings involving stress manipulation (see Masters, 1992; Hardy et al., 1996).

The results from the CSAI-2 anxiety scores resulted in an increase in both cognitive and somatic anxiety during the stress condition for all four groups that received the treatment, which provided additional support that the manipulation worked. The group means for both pre and post stress manipulation were lower than the values obtained by Hardy et al. (1996) in their use of the CSAI-2. Several participants however, noted that they did not expect themselves to fly very well at first because they knew nothing about flying. This was inherently different from a golf-putting task where subjects would probably be fairly confident that they could succeed, resulting in the initial stress for the present study to be lower. The post-test CSAI-2 measurements could have been low as well because the incentive for this study was positive. Unlike the golf studies, which told the participants that they could lose money, the present study informed the participants that they were in a position to win the money. So, despite the stress manipulation, the fact that they were told that they were flying well could have cause the stress levels to be lower. Even with these differences, the overall anxiety scores still increased for the groups that were stressed, which lend support to the effectiveness of the intervention.

Group Performance Changes

With the desired stress manipulation being validated, the differences between groups can be confidently attributed to the amount of explicit knowledge generated by each group. It was hypothesized that a characteristic learning curve for airspeed, altitude, and heading control would exist for all groups during testing. The data from experimentation demonstrated a characteristic reduction in RMS error over subsequent trials for each variable.

The most significant hypothesis for performance was that the implicit group would display the worst performance out of all of the groups for all test sessions. There was expected to be an even larger deviation between groups that the previous studies using the golf task, because the task was harder. Perhaps one of the most surprising results from the study, however, was that the performance change during the acquisition trials exhibited by each group was relatively equal despite the varying amount of explicit knowledge that each group had.

One explanation for the equal performance changes was that the effect of providing explicit knowledge was diminished because initial errors were great. One of the problems noted during the data analysis was that RMS error is affected greatly by highly deviant readings. Therefore, even if the explicit groups were eventually able to control a variable more accurately than the implicit group, the large initial deviations could have masked any difference.

There is however another possible explanation. It was hypothesized that implicit knowledge would become more important for the control of complex systems. This hypothesis was based on the analysis by Seger (1994) who included complexity as criteria for a task in which implicit learning would be most beneficial. It appears that this was true for the complex flight control task, where the implicit group seemingly performed just as well as those provided information. The differences only became apparent during the stress and retention trials. Analysis of the group by session error reduction for the stress and retention trials revealed that the implicit group was unable to maintain performance under these conditions. It is possible that the explicit knowledge becomes useful during a stressful situation or for long-term learning.

It was also hypothesized that the implicit group would only be able to control one variable at a time because of the inability to coordinate the instrument readings. Because a high degree of coordination is needed to sustain all three axes, the breakdown in the implicit performance during the stress condition follows the predicted hypothesis. The implicit group was able to effectively preserve the heading well, which was reported to be the easiest to control and maintain by participants. As a result of maintaining performance of the heading during the stressful condition however, the implicit group was unable to control the other two axes at the same time, resulting in decreased performance for both the airspeed and altitude. The explicit group on the other hand had no decrease. It is important to note however, that the explicit control group did perform worse for all three axes during the stress condition despite their established high number of explicit rules. This raises the question as to whether it was merely the presence of the dual task that caused the decreased performance.

Masters (1992) proposed that the cognitive resources of explicit learners were influenced under stress, reducing performance. If this were correct, one would have expected even greater performance discrepancies during stress for a flying task, since it is more cognitively demanding than a golf putt. While there were no significant differences exhibited between the implicit and explicit groups, the results do not seem to support Masters' viewpoint, especially since the most of the groups with high explicit knowledge actually improved during the stress condition. The results demonstrated that any advantage that implicit knowledge may have over explicit knowledge during stressful conditions might erode during more complex tasks.

Variability in Scanning Pattern

It was hypothesized that the explicit groups would have faster search rates as compared to the implicit group. There were, however, no group differences established for search rates. It was also hypothesized that the groups with explicit knowledge would have more fixations on relevant instruments. The hypothesized trends did occur even though there were no group differences noticed. The explicit and explicit control had the smallest number of fixations on the altimeter with an increased fixation pattern on the ADI, while the implicit group had the highest fixations on the altimeter. Data for the simple task displayed similar findings with the explicit and explicit control having more fixations on the VSI and ADI.

One reason for smaller group differences may have been due to the fact that there was little to no information available in the scenery that could be used for orientation. This could have caused increases on certain instrument fixations for the implicit group that would have otherwise been absent.

As described earlier attentional control is the ability to adaptively change attentional strategies during complex tasks (Gopher et al., 1994). In an attempt to make the flight performance calculation more relative by having the participants fly at straight and level flight, it also relegated the scanning patterns to a stable pattern that would be more consistent for every group.

For fixation duration, it was hypothesized that the explicit group would have shorter fixation durations on each instrument. There were no significant differences of note, however it important once again to point out that the subjects were still relative novices at flying at the end of testing and only had to maintain parameters rather than actively monitor changing variables like in previous experimentation upon which the hypothesis was based.

The limited flying time used for this experiment did not produce any differences in the search rate but was still able to reveal important differences in the fixation patterns exhibited by each group. The explicit groups fixated for longer on the instruments that would delineate more expert scanning patterns as mentioned earlier and could have led to superior performance for testing during more dynamic conditions.

Information Extraction

It was hypothesized that the explicit group would have the fastest response times as well as be the most accurate for slide reading. Once again however there were no significant differences found. There are several reasons why this may have occurred. In the first session no one knew how to read the instruments, causing similar errors. The second testing was done after each group had flown for 30 minutes trying to control the variables, so even though the groups varied in the amount of explicit knowledge, they still had figured out how to read the instrumentation by then. Prior research determined that experts have the rapid ability to detect deviations from normal parameters in instruments (DeMaio, Parkinson, & Crosby, 1978; DeMaio, Parkinson, Leshowitz et al., 1976). The present experiment however was done in a static non-flying environment. Perhaps it would have clarified the differences more profoundly if it were done as an "instrument check" while actually flying the simulator.

Effect of Stress on Complex Tasks

In the experiments detailed earlier by Masters (1992), and Hardy, et al. (1996), performance for those with explicit knowledge decreased slightly or remained the same under stress. The key result from this study was the finding that the explicit group did not have any decrease in performance during the stress condition. As hypothesized, the findings of the present study would provide an indication that explicit knowledge for complex actions can facilitate the development of expert performance patterns while being resistant to performance degradation under stress.

Just as important was the result that all explicit knowledge groups, improved during the retention phase. One seemingly consistent problem with research in the area of implicit and explicit learning is the vague discussion or interpretation of the amount of actual long-term learning that is achieved during the experimentation. Experiments have lacked any type of retention test and therefore have not fully explored the benefits or drawbacks of implicit or explicit learning. By including a retention test, the enduring qualities of different learning types could be evaluated.

Since tasks used for experimentation of this nature are usually novel to provide consistent group performance comparisons, it is easy to lose sight of one of the major pushes for this area of research: learning. It can clearly be argued that the performers even at the end of testing are still novices. A lingering problem, therefore, is that it is difficult to ascertain what role explicit knowledge actually plays once a task has become completely automatic. In essence, what is examined during testing is novices or early development. As discussed earlier, an explicit process can become automatic over time. Present studies therefore may only be testing the infancy of the curve, and as a result, be making an artificial distinction between the two processes. It is possible that explicit knowledge for the short term may hurt performance for certain tasks. However, explicit knowledge potentially lays the groundwork for more efficient, and consistent performances later on, and that this knowledge is, in fact, stress-resistant.

Therefore, it could be argued that when expert status is achieved and performance proceeds automatically, it's irrelevant how the knowledge is initially acquired. In order to evaluate this premise, research must be done on the long-term performance effects of explicit and implicit based processes. The present study sets the foundation for the argument that for long-term performance of complex tasks, more explicit knowledge would be beneficial. A recent study by Maxwell et al. (2000) performed a longitudinal study of explicit and implicit based performance for the golf-putting task from Masters (1992). Results from the study demonstrated that even after 3000 golf putts, the implicit group was unable to reach the performance levels of the explicit group. These results seemingly provide further evidence for the importance of explicit knowledge for long-term performance.

Since it is impossible to find a real world situation void of explicit knowledge, it certainly plays an important role for the performance by experts in any sport or skill.

Even in studies such as Masters (1992), and Hardy et al. (1996), the explicit group consistently achieved a higher level of performance as compared to the implicit group despite any decreases or leveling in performance noticed under stress. In all of these cases the fact remains that performance in the long run is superior when based upon explicit rules.

Further research efforts are needed, however, to establish a clearer definition of the benefits of both explicit and implicit learning, and their relation to automaticity. The current investigation is an introductory investigation into the role of implicit and explicit learning of complex cognitive and motor skills. Studies involving the implementation of more task-relevant stress variables such as changing weather conditions, instrument failures, or other in flight emergency situations might be a more logical extension of the current research for investigation of stress during flight. Attentional distractions, which could espouse implicit learning such as task relevant secondary tasks like spotting for planes, talking on the radio, etc. could also be implemented in future studies as well. Through the continued analysis of the influence of these learning strategies on performance, researchers will also be able to identify how to integrate their useful qualities. This will allow application of critical learning components to help increase performance during stress, and to achieve a faster transition to automaticity. The application of each of these issues will be vital to future learning paradigms.

APPENDIX A
EXPERIENCE QUESTIONNAIRE

1. Do you have a pilot's license? Yes [ ] No [ ]
2. If you do not have your pilot's license, what, if any, flight experience do you have? (Explain type and amount.)
3. If you do not have any flight experience, have you had any other exposure to flying an aircraft? Explain.
4. Do you play video games? Yes [ ] No [ ]
5. Do you have experience playing flight simulator games? Yes [ ] No [ ]
   - If yes, what flight simulator games have you played?
   - On average, how often do you play?

   Once a month [ ] Once a week [ ] Several times a week [ ] Every Day [ ]

   - In your estimate how good are you at these games?

   Poor Excellent

   1 2 3 4 5 6 7

1. Do you have experience playing other simulation games like racing, etc. Yes[ ] No [ ]
   - If yes, what other simulation games have you played?
   - On average, how often do you play?

   Once a month [ ] Once a week [ ] Several times a week [ ] Every Day [ ]

   - In your estimate how good are you at these games?

   Poor Excellent

   1 2 3 4 5 6 7

APPENDIX B
COMPETETIVE STATE ANXIETY INVENTORY – 2

	Not At All	Somewhat	Moderately So	Very Much So
1. I am concerned about this competition	1	2	3	4

Is this symptom facilitative or debilitative to your subsequent performance?
Very debilitative **Very Facilitative**
-3 -2 -1 0 1 2 3

2. I feel nervous.	1	2	3	4

Is this symptom facilitative or debilitative to your subsequent performance?
Very debilitative **Very Facilitative**
-3 -2 -1 0 1 2 3

3. I feel at ease.	1	2	3	4

Is this symptom facilitative or debilitative to your subsequent performance?
Very debilitative **Very Facilitative**
-3 -2 -1 0 1 2 3

4. I have self-doubts.	1	2	3	4

Is this symptom facilitative or debilitative to your subsequent performance?
Very debilitative **Very Facilitative**
-3 -2 -1 0 1 2 3

5. I feel jittery.	1	2	3	4

Is this symptom facilitative or debilitative to your subsequent performance?
Very debilitative **Very Facilitative**
-3 -2 -1 0 1 2 3

6. I feel comfortable. 1 2 3 4

Is this symptom facilitative or debilitative to your subsequent performance?
Very debilitative **Very Facilitative**
-3 -2 -1 0 1 2 3

7. I am concerned that I may not do as well in this competition as I could. 1 2 3 4

Is this symptom facilitative or debilitative to your subsequent performance?
Very debilitative **Very Facilitative**
-3 -2 -1 0 1 2 3

8. My body feels tense. 1 2 3 4

Is this symptom facilitative or debilitative to your subsequent performance?
Very debilitative **Very Facilitative**
-3 -2 -1 0 1 2 3

9. I feel self-confident 1 2 3 4

Is this symptom facilitative or debilitative to your subsequent performance?
Very debilitative **Very Facilitative**
-3 -2 -1 0 1 2 3

10. I am concerned about losing. 1 2 3 4

Is this symptom facilitative or debilitative to your subsequent performance?
Very debilitative **Very Facilitative**
-3 -2 -1 0 1 2 3

11. I feel tense in my stomach. 1 2 3 4

Is this symptom facilitative or debilitative to your subsequent performance?
Very debilitative **Very Facilitative**
-3 -2 -1 0 1 2 3

12. I feel secure. 1 2 3 4

Is this symptom facilitative or debilitative to your subsequent performance?
Very debilitative **Very Facilitative**
-3 -2 -1 0 1 2 3

13. I am concerned about choking under pressure. 1 2 3 4

Is this symptom facilitative or debilitative to your subsequent performance?
Very debilitative **Very Facilitative**
-3 -2 -1 0 1 2 3

14. My body feels relaxed. 1 2 3 4

Is this symptom facilitative or debilitative to your subsequent performance?
Very debilitative **Very Facilitative**
-3 -2 -1 0 1 2 3

15. I'm confident that I can meet the challenge. 1 2 3 4

Is this symptom facilitative or debilitative to your subsequent performance?
Very debilitative **Very Facilitative**
-3 -2 -1 0 1 2 3

16. I'm concerned about performing poorly 1 2 3 4

Is this symptom facilitative or debilitative to your subsequent performance?
Very debilitative **Very Facilitative**
-3 -2 -1 0 1 2 3

17. My heart is racing. 1 2 3 4

Is this symptom facilitative or debilitative to your subsequent performance?
Very debilitative **Very Facilitative**
-3 -2 -1 0 1 2 3

18. I'm confident about performing well. 1 2 3 4

Is this symptom facilitative or debilitative to your subsequent performance?
Very debilitative **Very Facilitative**
-3 -2 -1 0 1 2 3

19. I'm worried about reaching my goal 1 2 3 4

Is this symptom facilitative or debilitative to your subsequent performance?
Very debilitative **Very Facilitative**
-3 -2 -1 0 1 2 3

20. I feel my stomach sinking 1 2 3 4

Is this symptom facilitative or debilitative to your subsequent performance?
Very debilitative **Very Facilitative**
-3 -2 -1 0 1 2 3

21. I feel mentally relaxed 1 2 3 4

Is this symptom facilitative or debilitative to your subsequent performance?
Very debilitative **Very Facilitative**
-3 -2 -1 0 1 2 3

22. I'm concerned that others will be disappointed with my performance 1 2 3 4

Is this symptom facilitative or debilitative to your subsequent performance?
Very debilitative **Very Facilitative**
-3 -2 -1 0 1 2 3

23. My hands are clammy 1 2 3 4

Is this symptom facilitative or debilitative to your subsequent performance?
Very debilitative **Very Facilitative**
-3 -2 -1 0 1 2 3

24. I'm confident because I mentally picture myself reaching my goal 1 2 3 4

Is this symptom facilitative or debilitative to your subsequent performance?
Very debilitative **Very Facilitative**
-3 -2 -1 0 1 2 3

25. I'm concerned that I won't be able to concentrate 1 2 3 4

Is this symptom facilitative or debilitative to your subsequent performance?
Very debilitative **Very Facilitative**

-3 -2 -1 0 1 2 3

26. My body feels tight 1 2 3 4

Is this symptom facilitative or debilitative to your subsequent performance?
Very debilitative **Very Facilitative**

-3 -2 -1 0 1 2 3

27. I'm confident of coming through under pressure 1 2 3 4

Is this symptom facilitative or debilitative to your subsequent performance?
Very debilitative **Very Facilitative**

-3 -2 -1 0 1 2 3

APPENDIX C
INFORMED CONSENT

Please read this consent document carefully before you decide to participate in this study.

Protocol Title: Implicit and Explicit Learning: Performance considerations for complex tasks.

Principal Investigator: Ryan D. Sullivan B.S., Graduate Student, Department of Exercise and Sport Sciences, 375-7639

Supervisor: Christopher M. Janelle PhD., Assistant Professor, Department of Exercise and Sport Sciences, FLG 100, Phone: (352) 392-0584 (ext. 270)

Purpose of the research study:

The purpose of this study is to examine the visual search patterns of participants as they perform a flight simulation task as well as the effect of varying knowledge bases on performance during stress.

What you will be asked to do in the study:

There will be four test sessions, consisting of three segments for each test session, which will all take place in the Motor Behavioral Laboratory of the Florida Gymnasium. Prior to each test, you will be fitted with a heart rate monitor. During the first two segments you will be wear the ASL 5000 eye movement tracking system, which will monitor your gaze patterns. Your visual search patterns will be analyzed during two 10-minute flights on the Microsoft 2000 flight simulator program. During the third segment you will be asked to accurately extract information from 10 slides of an instrument panel. During the second and fourth test session you will also be asked to fill out a short questionnaire. The principle investigator will administer all segments of testing.

Time required:

The experiment will take approximately 1 hour for each of the four sessions for a total of 4 hours. Those randomly assigned to the explicit testing groups will incur an additional 30 minutes of training prior to the 2nd test session.

Risks and Benefits:

This research is considered minimal risk. The risks of harm anticipated in the proposed research is not greater than that ordinarily encountered in daily life or through routine physical or psychological examinations or tests. There is no benefit expected from participation in this study.

Compensation:

There will not be a standard compensation for participation in this research. Cash rewards of $50, $30, and $20 will be awarded for 1st, 2nd, and 3rd place, respectively, based upon performance during testing. Participation in this study is independent from any class or program and as such will not affect your grade or status in any program.

Confidentiality:

Your identity will be kept confidential to the extent provided by law. At the beginning of your participation, your information will be assigned a code number. The list connecting your name to this number will be locked in a filing cabinet in the Motor Behavior Lab of the Florida Gymnasium. When the study is completed and the data has been analyzed, the list will be destroyed. Your name will not be used in any subsequent report.

Video recordings will be made of your test sessions. Only those involved with the study will have access to the tapes for data analysis purposes only. At all other times the videotapes will be locked inside the Motor Behavior Lab of the Florida Gymnasium. After final analysis, the tapes will be erased.

Only group data will be reported. Data will never be identified individually.

Voluntary participation:

Your participation in this study is completely voluntary. There is no penalty for not participating.

There will be several questionnaires that will be filled out during testing. You do not have to answer any question that you do not wish to answer.

Right to withdraw from the study:

You have the right to withdraw from the study at anytime without consequence.

Whom to contact if you have questions about the study:

Ryan D. Sullivan B.S., Graduate Student, Department of Exercise and Sports Sciences, 375-7639.

Christopher M. Janelle PhD., Assistant Professor, Department of Exercise and Sports Sciences, FLG 100, Phone: (352) 392-0584 (ext. 270)

Whom to contact about your rights as a research participant in the study:

UFIRB Office, Box 112250, University of Florida, Gainesville, FL 32611-2250; ph 392-0433.

Agreement:

I have read the procedure described above. I voluntarily agree to participate in the procedure and I have received a copy of this description.

Participant's Signature: ______________________________

Date: ____________

Principal Investigator's Signature: ________________________

Date: ____________

APPENDIX D
PREPARED INSTRUCTIONS

Control

You will participate in four test sessions during this experiment. There will be one pretest today to establish your baseline performance. There will then be two practice sessions. The final test session will be the one that counts toward the competition for the cash prizes. Since it is a competition, your chance at winning the cash prize depends on your performance during the final test session. Since we are concerned about the learning process involved with flying, you will be given little information on how to fly. The goal is to improve your performance over practice. There are six main instruments that you should be concerned with. (show) Just concentrate on the relationships between instruments and try to figure out what information each provides as you practice keeping the aircraft straight and level.

Explicit

You will participate in four test sessions during this experiment. There will be one pretest today to establish your baseline performance. There will then be two practice sessions. The final test session will be the one that counts toward the competition for the cash prizes. Since it is a competition, your chance at winning the cash prize depends on your performance during the final test session. It is therefore important that you concentrate on the rules that will be provided to you today in order to increase your performance for the competition. I will now give you a short written description of important information needed for performance in your task.

Explicit Control

You will participate in four test sessions during this experiment. Since it is a competition, your chance at winning the cash prize depends on your performance during the test sessions. It is therefore important that you concentrate on the rules that will be provided to you today in order to increase your performance for the competition. I will now give you a short written description of important information needed for performance in your task.

(After reading instructions)

For this experiment, I'm also looking at the acquisition of skill over time while having to simultaneously perform another task. Therefore, while flying you will hear a click from a metronome (demonstrate). Every time that you hear a click you must say a random letter. Make sure that it is random; try to avoid spelling a word, or doing the alphabet song (demonstrate).

Implicit

You will participate in four test sessions during this experiment. There will be one pretest today to establish your baseline performance. There will then be two practice sessions. The final test session will be the one that counts toward the competition for the cash prizes. Since it is a competition, your chance at winning the cash prize depends on your performance during the final test session. Since we are concerned about the learning process involved with learning how to fly, you will be given little information on how to fly. The goal is to improve your performance over practice. There are six main instruments that you should be concerned with. (show) Just concentrate on the relationships between instruments and try to figure out what information each provides as you practice at keeping the aircraft straight and level.

For this experiment, I'm also looking at the acquisition of skill over time while having to simultaneously perform another task. Therefore, while flying you will hear a click from a metronome (demonstrate). Every time that you hear a click you must say a random letter. Make sure that it is random; try to avoid spelling a word, or doing the alphabet song (demonstrate).

Implicit Control

You will participate in four test sessions during this experiment. Since this is a competition, your chance at winning the cash prize depends on your performance during the test sessions.

Since we are concerned about the learning process involved with learning how to fly, you will be given little information on how to fly. The goal is to improve your performance over practice. There are six main instruments that you should be concerned with. (show) Just concentrate on the relationships between instruments and try to figure out what information each provides as you practice at keeping the aircraft straight and level.

For this experiment, I'm also looking at the acquisition of skill over time while having to simultaneously perform another task. Therefore, while flying you will hear a click from a metronome (demonstrate). Every time that you hear a click you must say a random letter. Make sure that it is random; try to avoid spelling a word, or doing the alphabet song (demonstrate).

Complex

For this task, you must fly the simulator in straight and level flight. You must maintain a constant heading, altitude, and airspeed. Specifically you must maintain a heading of 060, an altitude of 3000 ft., and a speed of 100 knots. These values are on a post-it note next to the joystick for your reference while flying if needed. The aircraft will begin at these values when the simulation begins. Your control of the airplane will be through the joystick, and the throttle control on the side. Please make sure that you do not hit any other buttons while flying.

Simple

For this task you must fly the aircraft in level flight. All you are asked to maintain is the proper altitude of 3000 ft. This value is on a post-it note next to the joystick for your reference while flying if needed. The aircraft will begin at 3000 ft when the simulation begins. Do not worry about other factors such as airspeed or direction. Your control of the airplane will be through the joystick, and the throttle control on the side. Please make sure that you do not hit any other buttons while flying.

Slide

For this task you will be shown 10 slides of an aircraft instrument panel in various configurations. What you need to do is to record the heading, speed, and altitude of the aircraft for each slide. You will be scored on your accuracy as well as your speed. So while it is important to do the task as fast as you can, you will want to be accurate at the same time. Please record a value of some kind even if you are unsure of the correct answer. I will now demonstrate how to use the slide advancement device. (show)

APPENDIX E
SLIDE RESPONSE

Slide Order #_____	Altitude	Speed	Heading
_____	__________ft.	__________knots	__________deg.
_____	__________ft.	__________knots	__________deg.
_____	__________ft.	__________knots	__________deg.
_____	__________ft.	__________knots	__________deg.
_____	__________ft.	__________knots	__________deg.
_____	__________ft.	__________knots	__________deg.
_____	__________ft.	__________knots	__________deg.
_____	__________ft.	__________knots	__________deg.
_____	__________ft.	__________knots	__________deg.
_____	__________ft.	__________knots	__________deg.

APPENDIX F
REPORTING EXPLICIT RULES

Now that the test sessions are completed, what I would like you to do is to write down all of the information that you learned about flying the simulator during the past few days. They may include anything provided to you, or anything you have learned on your own. Please write the information in bullet format and use a new line for each additional piece of information. What I would like you to include is anything you know about what information the instruments provides, how you control the aircraft using the joystick and throttle, and any interactions they may have with the aircraft instruments, as well as any relationships that you have noticed between instruments.

APPENDIX G
EXPLICIT FLIGHT INFORMATION

Straight-and-Level Flight

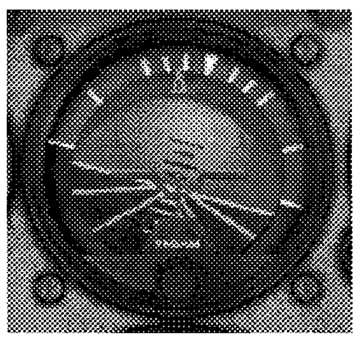
The key to straight-and-level flight requires that you make **smooth, small** corrections.

When you are flying, concentrate on making corrections in two main areas:

1. Holding a constant altitude and airspeed.
2. Holding a constant heading.

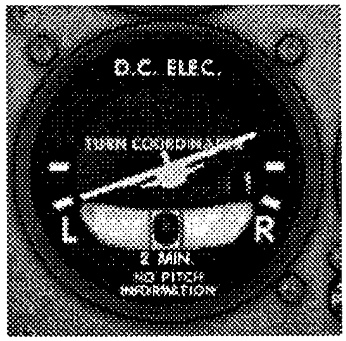
There are several instruments that allow you to do this, which will now be explained.

Attitude Indicator



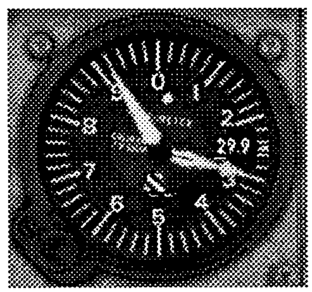
This is the main instrument that will help you to maintain straight-and-level flight. The attitude indicator is an artificial representation of the real horizon. The top is blue, representing the sky; the bottom is brown, representing the ground. The white line between these areas represents the artificial horizon. The orange in the middle represent your plane's wings. The instrument simulates your actual aircraft orientation in the air. For example, if you push the joystick forward, the orange "plane" will dip toward the brown ground. If you move the joystick to the left, the orange "plane" will bank according to the horizon, as seen on the instrument above. Since you want to fly straight and level, you want to **keep the orange of your wings level, right on the white line of the artificial horizon**. That way you know you are not going up, or down, right or left. This will help with your heading, airspeed and altitude. If you keep your plane level on this instrument you will maintain the same direction, and altitude. Pilots spend about 80% of the time on this instrument and then quickly glance at the supporting instruments to check their position and to make corrections. These supporting instruments will now be explained.

Turn Coordinator



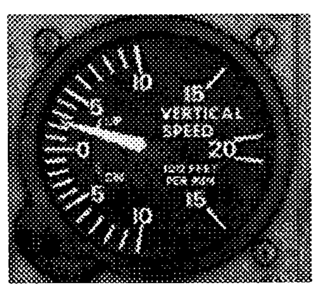
This is another instrument that you can check real quickly to see if you are flying level. If the airplane on the instrument is banked then you are not level, but **if the wings are straight and level, so is your aircraft.** The plane above obviously is not level.

Altimeter



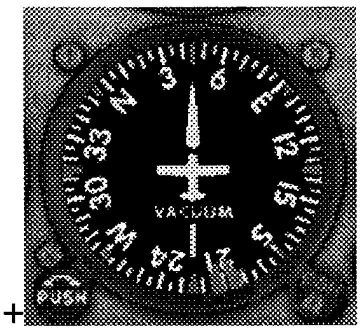
The altimeter tells you your altitude above ground in feet. **The long needle points to hundreds of feet. The short needle points to thousands of feet.** For the example above, the long needle is on the 9 and the short needle is close to the 3, so you're at 2,900 ft.

Vertical Speed Indicator



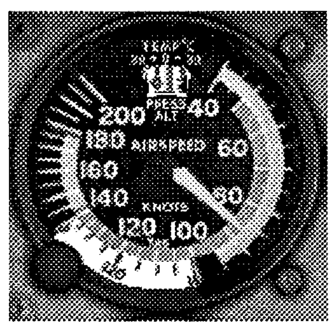
This is another instrument that tells you whether you are gaining or losing altitude. It tells how many hundreds of feet/min you are gaining or losing per minute. Ideally you should **keep this at zero** since you want to keep a constant altitude. The above instrument is at a positive 200 ft/min. If this were maintained, this aircraft would increase its altitude.

Heading Indicator



The heading indicator is very simple to read. It is broken into 360 degrees like a normal compass. **It tells you what direction your plane is headed towards.** This plane is headed in a 45 degrees heading.

Airspeed Indicator



This instrument is very simple as well. It tells the speed of the aircraft in knots. The above is at 86 knots. Your airspeed is related to your altitude. If you push the nose of the plane down to lose altitude, you will gain in speed. Similarly if you pull the nose up to gain altitude, you will lose speed. To control the plane's airspeed you use the throttle control. Ideally you want to establish your heading and altitude and then adjust the throttle accordingly. If you are too slow, increase the throttle, and decrease it accordingly if you are too fast. Remember slow corrections are best. While maintaining the correct direction and altitude, slowly increase or decrease the throttle until your desired speed is reached. Generally you will achieve the same speed every time with the same throttle setting, so once you figure the correct position you can simply put it to the correct throttle position and you will be close to your desired speed if you keep it straight and level.

APPENDIX H
POST EXPERIMENT QUESTIONNAIRE

Please take a few minutes to respond to this brief questionnaire regarding your experience in this experiment.

1. How lifelike was the simulation (to what extent did you feel like you were flying an aircraft)?

Not at all — Very much so
1 2 3 4 5 6 7

2. What did you tend to look at most often while flying the simulator? (Use back if necessary)

3. If you had to generate random letters, where did you direct most of your attention while flying?

Letter Generation — Flying
1 2 3 4 5 6 7

4. Did the letter generation affect your performance?

Not at all — Very much so
1 2 3 4 5 6 7

5. If you were told that a video of your participation might be used for a Discovery channel special did you believe that this was the case?

Not at all — Very much so
1 2 3 4 5 6 7

6. If you were told you could receive $50 for participation, did you believe it?

Not at all — Very much so
1 2 3 4 5 6 7

7. If you were shown a graph depicting how close you were to winning the prize money, did you believe what you were shown?

Not at all — Very much so
1 2 3 4 5 6 7

8. Did knowing that you were a competing against other people, that you had a chance to be a part of a Discovery special, and that you had a chance to win $50 influence your motivation, anxiety level, or confidence level in any way?

Not at all — Very much so
1 2 3 4 5 6 7

9. If you answered 4-7 in #9 above, how did these factors affect you? (Use back if necessary)

10. Do you tend to feel anxious in competitive situations?

Not at all — Very much so
1 2 3 4 5 6 7

11. Any other comments? (Use back if necessary)

As a reminder, this is ongoing research, so please do not discuss this study or any of its testing procedures with anyone, whether they are taking part in the experiment or not. Thank you for your time and participation. I will let you know if you win the $50, $30, or $20 prize.

APPENDIX I
PARTICIPANT DEBRIEFING

The purpose of this post-experiment debriefing is to fully explain to you information concerning the purpose behind this research.

The underlying purpose of this experiment was to evaluate your response to stress while flying the simulator. Different participant groups were provided with varying amounts of information on how to properly control the aircraft. We were concerned as to what affect these differences would have on your performance.

In order to invoke a stress response during the last test session we combined the use of camera observation and cash incentives.

During the final test session you were informed that the videotape of your performance could be used for submission in a professional production highlighting this experiment. This in fact was not true. The tape will not be used for any such purpose.

During the final session you were also informed that you were close to winning one of the cash prizes and that your performance on the final test would actually determine whether you received the money or not. This also was not true. The cash prizes will still be distributed, however the researchers will not know your actual performance or position in relation to other participants until final data interpretation is made. Once these are determined, the cash rewards will be provided to those with the top three overall performances. You will be notified as to whether you have won or not.

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BIOGRAPHICAL SKETCH

Ryan D. Sullivan is a 2nd Lieutenant in the U.S. Air Force. Ryan was born in 1977 and grew up in Hamilton, MI. He received a Bachelor of Science in Biology and his commission in June 1999 from the U.S. Air Force Academy in Colorado Springs, Colorado. Upon completion of the Master of Science in Exercise and Sport Science at the University of Florida, he will be attending Undergraduate Pilot Training for the U.S. Air Force at Vance Air Force Base in Enid, OK.

Author: Ryan D. Sullivan
Title: Pilot Skill Development With Implicit And Explicit Learning: Considerations For Task Complexity
Military Rank: 2nd Lieutenant
Service Branch: USAF
Date: 2000
Number of pages: 104
Degree Awarded: MSESS - Master of Science in Exercise and Sport Sciences
Name of Institution: University of Florida

Abstract:

The focus of the present study was to evaluate aspects of the learning process that aid expertise development for aircraft pilots. Research in learning strategies has recently focused on implicit and explicit learning to determine if it is more important to focus on conscious facts or unconscious procedural performance during the learning process. Of particular concern for the current investigation was to determine if explicit knowledge is necessary for automatic performance of complex cognitive motor skills such as flying.

Several recent studies have proposed that explicit knowledge may be detrimental for performance under the cognitive loads of stress. This study therefore examined groups of novice pilots who learned how to fly a flight simulator either implicitly or explicitly to see what effect the learning process had on performance during stress and a subsequent retention test. Participant scanning patterns were also analyzed using an infrared eye tracker to determine which group would exhibit superior attentional control.

Analysis revealed that the implicit group was able to match the performance of the explicit groups during acquisition trials but performed worse during the stress and retention periods. The explicit groups also fixated for longer on instruments that would delineate more expert scanning patterns. The results demonstrated that explicit knowledge for more complex tasks is not detrimental, and can lead to increased long-term performance.

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